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Public Health Assessment for

NORFOLK NAVAL BASE
(a/k/a SEWELLS POINT NAVAL COMPLEX)
NORFOLK, NORFOLK CITY COUNTY, VIRGINIA
EPA FACILITY ID: VA6170061463
SEPTEMBER 16, 2002

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
Agency for Toxic Substances and Disease Registry

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PUBLIC HEALTH ASSESSMENT

NORFOLK NAVAL BASE (SEWELLS POINT NAVAL COMPLEX)

NORFOLK, NORFOLK CITY COUNTY, VIRGINIA

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Prepared by:

Federal Facilities Assessment Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry

THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment was prepared by ATSDR pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6)), and in accordance with our implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate.

In addition, this document has previously been provided to EPA and the affected states in an initial release, as required by CERCLA section 104 (i)(6)(H) for their information and review. The revised document was released for a 30-day public comment period. Subsequent to the public comment period, ATSDR addressed all public comments and revised or appended the document as appropriate. The public health assessment has now been reissued. This concludes the public health assessment process for this site, unless additional information is obtained by ATSDR which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

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FOREWORD

The Agency for Toxic Substances and Disease Registry, ATSDR, was established by Congress in 1980 under the Comprehensive Environmental Response, Compensation, and Liability Act, also known as the *Superfund* law. This law set up a fund to identify and clean up our country's hazardous waste sites. The Environmental Protection Agency, EPA, and the individual states regulate the investigation and clean up of the sites.

Since 1986, ATSDR has been required by law to conduct a public health assessment at each of the sites on the EPA National Priorities List. The aim of these evaluations is to find out if people are being exposed to hazardous substances and, if so, whether that exposure is harmful and should be stopped or reduced. If appropriate, ATSDR also conducts public health assessments when petitioned by concerned individuals. Public health assessments are carried out by environmental and health scientists from ATSDR and from the states with which ATSDR has cooperative agreements. The public health assessment program allows the scientists flexibility in the format or structure of their response to the public health issues at hazardous waste sites. For example, a public health assessment could be one document or it could be a compilation of several health consultations the structure may vary from site to site. Nevertheless, the public health assessment process is not considered complete until the public health issues at the site are addressed.

Exposure: As the first step in the evaluation, ATSDR scientists review environmental data to see how much contamination is at a site, where it is, and how people might come into contact with it. Generally, ATSDR does not collect its own environmental sampling data but reviews information provided by EPA, other government agencies, businesses, and the public. When there is not enough environmental information available, the report will indicate what further sampling data is needed.

Health Effects: If the review of the environmental data shows that people have or could come into contact with hazardous substances, ATSDR scientists evaluate whether or not these contacts may result in harmful effects. ATSDR recognizes that children, because of their play activities and their growing bodies, may be more vulnerable to these effects. As a policy, unless data are available to suggest otherwise, ATSDR considers children to be more sensitive and vulnerable to hazardous substances. Thus, the health impact to the children is considered first when evaluating the health threat to a community. The health impacts to other high risk groups within the community (such as the elderly, chronically ill, and people engaging in high risk practices) also receive special attention during the evaluation.

ATSDR uses existing scientific information, which can include the results of medical, toxicologic and epidemiologic studies and the data collected in disease registries, to determine the health effects that may result from exposures. The science of environmental health is still developing, and sometimes scientific information on the health effects of certain substances is not available. When this is so, the report will suggest what further public health actions are needed.

Conclusions: The report presents conclusions about the public health threat, if any, posed by a site. When health threats have been determined for high risk groups (such as children, elderly, chronically ill, and people engaging in high risk practices), they will be summarized in the conclusion section of the report. Ways to stop or reduce exposure will then be recommended in the public health action plan.

ATSDR is primarily an advisory agency, so usually these reports identify what actions are appropriate to be undertaken by EPA, other responsible parties, or the research or education divisions of ATSDR. However, if there is an urgent health threat, ATSDR can issue a public health advisory warning people of the danger. ATSDR can also authorize health education or pilot studies of health effects, fullscale epidemiology studies, disease registries, surveillance studies or research on specific hazardous substances.

Community: ATSDR also needs to learn what people in the area know about the site and what concerns they may have about its impact on their health. Consequently, throughout the evaluation process, ATSDR actively gathers information and comments from the people who live or work near a site, including residents of the area, civic leaders, health professionals and community groups. To ensure that the report responds to the community's health concerns, an early version is also distributed to the public for their comments. All the comments received from the public are responded to in the final version of the report.

Comments: If, after reading this report, you have questions or comments, we encourage you to send them to us.

Letters should be addressed as follows:

Attention: Chief, Program Evaluation, Records, and Information Services Branch, Agency for Toxic Substances and Disease Registry, 1600 Clifton Road (E56), Atlanta, GA 30333.

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AOC	area of concern
AS/SVE	air sparging/soil vapor extraction
ATSDR	Agency for Toxic Substances and Disease Registry
B2EHP	bis(2-ethylhexyl)phthalate
CAA	Clean Air Act
CDC	Centers for Disease Control and Prevention
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CREG	cancer risk evaluation guide
CSF	cancer slope factor
CV	comparison value
1,1-DCE	1,1-dichloroethene
1,2-DCA	1,2-dichloroethane
1,2-DCE	1,2-dichloroethene
EMEG	environmental media evaluation guide
EPA	U.S. Environmental Protection Agency
FFA	Federal Facilities Agreement
FS	feasibility study
IRP	Installation Restoration Program
LOAEL	lowest observed adverse effect level
LTHA	lifetime health advisory
MCL	maximum contaminant level
mg/kg	milligrams per kilogram
mg/kg/day	milligrams per kilogram per day
MRL	minimal risk level
N/A	not applicable
NM	naval magazine
NOAEL	no observed adverse effect level
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NSN	Naval Station Norfolk
OU	operable unit
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	tetrachloroethylene (also known as perchloroethylene or PERC)
pCi/g	picoCuries per gram
pCi/L	picoCuries per liter
PHAP	public health action plan
RAB	restoration advisory board
RBC	risk-based concentration
RCRA	Resource Conservation and Recovery Act

RfD	reference dose
RI	remedial investigation
RMEG	reference dose media evaluation guide
ROD	record of decision
RRR	relative risk ranking
SDWA	Safe Drinking Water Act
SSA	site screening area
SVOC	semi-volatile organic compound
SWMU	solid waste management unit
1,1,1-TCA	1,1,1-trichloroethane
1,2,2-TCA	1,1,2-trichloroethane
TCE	trichloroethylene
μg/dL	micrograms per deciliter
μg/L	micrograms per liter
$\mu g/m^3$	micrograms per cubic meter
UST	underground storage tank
VDEQ	Virginia Department of Environmental Quality
VDOH	Virginia Department of Health
VDSS	Virginia Department of Health's Division of Shellfish Sanitation
VOC	volatile organic compound
VMRC	Virginia Marine Resources Commission

SUMMARY

Naval Station Norfolk (NSN) is the largest naval base in the United States. Its mission is to provide fleet support and readiness for the U.S. Atlantic Fleet. The base is comprised of the two installations previously known as Naval Air Station Norfolk and Naval Station Norfolk, both established in 1917. NSN is located on 4,631 acres on the Sewells Point peninsula in northern Norfolk, Virginia. Willoughby Bay is to the north and the Elizabeth River is to the west. Mason Creek forms a portion of NSN's eastern border. Residential, commercial, and industrial areas are to the east and south, as well as being inset into the southwestern portion of the base. This part of Norfolk, which includes the Glenwood Park community, is surrounded by the base on three sides and the Elizabeth River to the west. NSN is fenced, and public access is not allowed.

Activities conducted at NSN include defueling, refueling, painting, paint stripping, equipment cleaning, engine maintenance, sandblasting, metal plating, and loading and unloading of products used aboard vessels. In 1983, efforts began to identify site-related contamination resulting from the handling and disposal of products used at the base. Twenty-two sites were identified under the U.S. Department of Defense's Installation Restoration Program (IRP). On April 1, 1997, the U.S. Environmental Protection Agency (EPA) added the base to the National Priorities List. Since then, 20 other potentially-contaminated areas identified as solid waste management units have been designated areas of concern (AOCs) or site screening areas (SSAs). An investigation of each IRP site, AOC, and SSA has been completed or is under way. Based on the results at each site, appropriate actions that are protective of human health will be selected.

The Agency for Toxic Substances and Disease Registry (ATSDR) visited NSN in 1998 and 2000 to collect information about how people on and off site might be exposed to environmental contamination, to obtain environmental sampling data, and to learn about community health concerns. ATSDR obtained additional information from the city of Norfolk, Norfolk Department of Public Health, Virginia Department of Health, Virginia Department of Environmental Quality (VDEQ), and EPA. ATSDR prepared this public health assessment to evaluate past, current, and potential future exposures to contaminants originating at NSN. We evaluated exposures to on-site and off-site drinking water and to fish and shellfish from Willoughby Bay. We also addressed the community's concerns, including those about potential public health effects to the Glenwood Park community and to children in the vicinity of the Camp Allen Elementary School. ATSDR concluded that these potential exposures would be too low to cause any adverse health effects.

NSN has identified groundwater contamination in both the shallow and deep aquifers underlying the base. The contamination extends north and west of Area A of the Camp Allen Landfill and southeast of Area B of the landfill. A groundwater treatment system has been installed in the Camp Allen Landfill area. Low levels of volatile organic compounds (VOCs) were detected in a few isolated instances in Glenwood Park wells in 1991. The detected levels of contaminants

would not be expected to result in adverse health effects and are not thought to be related to groundwater contamination originating from NSN.

The city of Norfolk provides drinking water to properties within the city, including NSN, from lakes, rivers, and wells more than 2 miles from NSN. The only identified wells located near the base that draw shallow groundwater are in the Glenwood Park community and are not used for drinking water. Because no one drinks water from the shallow aquifer, no public health hazard exists. There are no wells drawing drinking water from the deep aquifer downgradient of site-related contamination. Thus, deep groundwater poses no public health hazard.

In response to a request made at a NSN Restoration Advisory Board meeting in 1998, ATSDR evaluated available data relating to NSN drinking fountains and faucets. Some locations have been sampled for lead and copper, which can leach into water from water distribution pipes. Both the city and the Navy take measures to reduce the potential for exposure to metals from pipes. Most available samples contained concentrations of lead and copper that would not be expected to result in adverse health effects under infrequent exposure scenarios. The only location where ATSDR found a recent pattern of lead concentrations exceeding regulatory limits was a faucet at Building Z-103. ATSDR recommends that the Navy verify that this faucet is not routinely used for drinking water. If the Navy determines that it is, ATSDR recommends that the faucet be resampled. If contaminant levels exceed safe limits, the Navy should take appropriate measures to ensure that people are not exposed to these levels of contaminants.

ATSDR reviewed all available surface water, sediment, and fish and shellfish samples collected from Willoughby Bay, as well as available information about potential fish and shellfish consumption patterns. A limited number of fish and shellfish samples collected between 1971 and 2001 contained slightly elevated levels of some metals, but most of these metals were not present at levels that would pose a potential public health hazard. Detected levels of zinc in some samples, however, could have caused temporary and reversible acute effects (gastrointestinal distress or short-term decreases in cortisol, a hormone produced by the body in response to stress). These zinc levels will not result in any long-term adverse health effects. Because the small number of samples analyzed precluded a definitive evaluation, ATSDR recommended in spring 2001 that VDEQ collect a variety of seafood species from Willoughby Bay and analyze them for arsenic and zinc, among other metals. VDEQ adopted these recommendations. ATSDR reviewed the sampling results in summer 2002 and determined that the contaminant levels in these samples (including zinc levels) would not result in any long-term adverse health effects.

As a part of our exposure evaluation and in response to community concerns, ATSDR evaluated potential exposures to children in the vicinity of the Camp Allen Elementary School. Elevated concentrations of a few contaminants have been detected near the school (southeast of NSN's Camp Allen Landfill) in groundwater, soil, and drainage ditch surface water and sediment. Because the detected concentrations are relatively low and exposures are expected to be limited and incidental, contact with contaminants would not be expected to result in adverse effects to and incidental, contact with contaminants would not be expected to result in adverse effects to children. Indoor air samples collected in 1992 from the school and the nearby base brig did not contain levels of contaminants that would result in adverse health effects. If future groundwater monitoring indicates that substantial groundwater contamination is migrating beneath the school or other areas where people live or work, ATSDR recommends the Navy evaluate the appropriateness of collecting additional indoor air samples.

BACKGROUND

Site Description and History

The largest naval installation in the country, Naval Station Norfolk (NSN) provides facilities and support for Navy vessels, aircraft, and other activities of the United States Atlantic Fleet. NSN is located on 4,631 acres. It is in the northern portion of Norfolk, about 90 miles southeast of Richmond, Virginia, and 185 miles south of Washington, D.C. (see Figure 1). The base is sited on a peninsula known as Sewells Point. Willoughby Bay is to the north. The Elizabeth River is to the west, and the tidal basin at the confluence of the Elizabeth and James Rivers, known as Hampton Roads, is to the northwest. Mason Creek forms a portion of NSN's eastern boundary. Norfolk lies east and south of the base. A part of Norfolk also is inset into the southwestern portion of the base, along the Elizabeth River. This area, which includes the Glenwood Park community, is surrounded by the base on three sides. The surrounding land use is primarily industrial, mixed with commercial and residential areas. Shipping facilities are located in the waterfront area south of the base, and there are some residential areas to the south and east (CH2MHILL 1997a, 1999; FFA 1999).

Effective February 1999, the installations then known as Naval Station Norfolk and Naval Air Station Norfolk were merged into a single installation called Naval Station Norfolk. The naval base was originally established on 474 acres known as Sewells Point Naval Complex in June 1917, to support the war effort. Naval facilities were commissioned as the Hampton Roads Naval Operating Base in October 1917. The Naval Air Station (originally named Naval Air Detachment, Curtiss Field, Newport News) started training aviators in May 1917. Five months later, it was moved across the James River adjacent to Hampton Roads Naval Operating Base. Planes were stationed in Norfolk to patrol the Atlantic Coast, and the site also housed a training center. Significant expansion occurred during and after World War II by dredging and filling operations and land acquisition (EDAW 1995; Naval Station Norfolk n.d.a.).

The mission of the base is to provide fleet support and readiness for the Atlantic Fleet. Approximately 105 ships are stationed at the base. There are approximately 260 tenants supporting Navy activities on site (Naval Station Norfolk n.d.a.; ATSDR-DHAC 1998a). Maintenance and repair work conducted at NSN include defueling, refueling, utilities hook-up, painting, paint stripping, patching, cleaning, engine maintenance, sandblasting, and metal plating. Fuels, oils, and other products used aboard vessels are also loaded and unloaded at the base (ATSDR-DHAC 1998a). The majority of contamination identified at the base has resulted from the handling and disposal of products used at the facility over time, including solvents, corrosives, paints, electroplating wastes, petroleum products, oils, and lubricants (EPA 1999).

Remedial and Regulatory History

In February 1983, an initial assessment study of the base was completed. Available records, site reconnaissance, and interviews with employees resulted in the identification of 18 possible areas (termed Sites 1 through 18) where contaminants might have affected the environment and the recommendation that six of the areas be investigated further. Subsequent confirmation studies evaluated the extent of contamination at and the possibility of chemical migration from the six sites of concern (Sites 1 through 6). The other sites were recommended for no further action, although cleanup activities were conducted at some of them (Sites 11, 14, 15, 16, and 17) (Baker 1993; CH2MHILL 1999a). (See Appendix A, which summarizes available information about sites that have been or will be investigated.)

In April 1986, a fire started at building V-60 and spread to building V-90. Transformers containing polychlorinated biphenyls (PCBs) ruptured from the heat, resulting in the spread of PCB contamination. This area was designated Site 19, and cleanup of the site was completed in 1991. By May 1993, three other areas had been added to the list of sites to be investigated under the Department of Defense's Installation Restoration Program (IRP) and designated Sites 20 through 22. (See Figure 2, which depicts the IRP sites.)

In 1996, the Navy and U.S. Environmental Protection Agency (EPA) identified 148 potentially contaminated sites on the basis of an EPA Resource Conservation and Recovery Act (RCRA) facility assessment, aerial photography provided by EPA's Environmental Photographic Interpretation Center, and field inspections. Sampling has been performed at selected sites and reported in two relative risk ranking data collection sampling and analysis reports released in 1996. On the basis of these sampling results, 25 solid waste management units (SWMUs) were initially recommended for additional evaluation. Another 8 SWMUs were added in 1997 and 1998. A removal action was conducted at SMWU 1 as part of the sediment removal at the CD Landfill in 1997, and the SMWU was recommended for no further action. SMWU 37 and other potentially contaminated sites that contain underground and aboveground storage tanks are being addressed in accordance with applicable Commonwealth of Virginia regulations. The base stormwater drainage system, designated SWMU 36, is undergoing an assessment and rehabilitation project, and no further investigation of the site as a SWMU is planned.

On April 1, 1997, pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), EPA added the base to the National Priorities List (NPL). That summer, a groundwater extraction and treatment system and a soil vapor extraction system began operating at the Camp Allen Landfill (Site 1). Drums containing waste solvents and contaminated soil have been excavated from the landfill area and disposed of off site. In 1998, groundwater treatment systems and soil vapor extraction systems began operating at Site 3 (Q-Area Drum Storage) and Site 20 (Building LP-20), contaminated soil was removed from Site 22 (Camp Allen Salvage Yard), and a record of decision (ROD) was signed for Site 6 (CD Landfill). The ROD for the CD Landfill requires it to be capped, groundwater to be monitored, and nearby contaminated sediment to be excavated. In 1999, the CD Landfill cap was installed. Soil was also removed from Site 5 (Pesticide Disposal Site) in 1999, and a sediment removal and soil paving/cover was conducted at Site 2 (NM Slag Pile). In 2000, work on a facility-wide background study and an ecological study of Bousch Creek began (LANTDIV 2000; CH2MHILL 2000d).

The Navy entered into a Federal Facilities Agreement (FFA) with EPA, effective February 1999, governing investigation and remediation activities at NSN. EPA and the Navy agreed that no further action was necessary at Sites 7 through 18, and 10 SWMUs were recommended for no further action. The FFA also grouped five SWMUs into four site screening areas (SSAs) and 15 SWMUs into eight areas of concern (AOCs) (FFA 1999). Table 1 lists the SSAs and AOCs and the SWMUs each comprises, and Figure 3 depicts the SWMUs. SSAs are subject to the site screening process to determine whether contamination has been released to the environment from them. Site investigations were completed for each SSA in 1998 or 1999, and further plans for each SSA will be determined after the results of a facility-wide background study become available. AOCs undergo review to determine whether they should be converted to SSAs or they require no further action. In May 2000, the Navy determined that no further action was required at the sites that had been designated AOCs 1, 3, 7, and 8. The Navy plans to further investigate AOCs 2, 4, 5, and 6 (CH2MHILL 2000d).

ATSDR Activities

In July 1998, the Agency for Toxic Substances and Disease Registry (ATSDR) conducted an initial site visit and met with representatives of Naval Station Norfolk, the Atlantic Division of the Naval Facilities Engineering Command, and the Naval Environmental Health Center, as well as representatives of other interested governmental agencies. ATSDR also attended a Restoration Advisory Board (RAB) meeting to solicit community concerns about the base (ATSDR-DHAC 1998a). On October 29, 1998, ATSDR released a health consultation containing a summary of potential public health issues at Naval Station Norfolk.

During the July 1998 site visit, ATSDR observed that the fence around the Camp Allen Salvage Yard (Site 22) was not intact. Since the salvage yard is not within the fenced part of NSN and is not far from the Camp Allen Elementary School, ATSDR recommended that it be repaired to prevent access by trespassers. Removal of contaminated surface soil at the site began 2 weeks after ATSDR's visit, and the fence was repaired in October 1998 (ATSDR-DHAC 1998b; Heaney 1999). The Navy is committed to keeping the fence intact (Naval Station Norfolk 2000).

In May 2000, ATSDR conducted another site visit to gain an understanding of current site conditions and of the status of remedial actions, as well as to collect site-related documents and environmental data.

As a part of other work in the Hampton Roads area, ATSDR will be reviewing studies by other agencies on the capture, consumption patterns, and potential exposure of recreational and subsistence fishers, and consumers of local seafood to contaminants present in area waters. Potential sources of contamination to seafood include various federal government and private industrial NPL sites, as well as associated regional and local point and non-point sources from surrounding residential, urban, and industrial areas. It is not a goal of this review to identify where and how seafood species come into contact with environmental contaminants. The goal is to understand how to provide adequate guidance to prevent exposures to concentrations of chemicals in the local seafood that could cause adverse health effects.

Additionally, ATSDR realizes that a number of stakeholders (local private citizens; environmental groups; community groups; local, state, and federal agencies; academia; and industries) have actively been looking at seafood issues in the Elizabeth River watershed for decades. *As a part of this regional study, ATSDR will be consulting with stakeholders to identify and discuss issues, as well as to share and evaluate additional information, relating to possible seafood contamination in the region.*

Demographics and Land Use

At the time of the 1990 U.S. Census, the total population within 1 mile of the site was 74,409. Of these people, about 71% were white, about 23% were black, and the remaining individuals were of other racial origins. The population included 6,978 children under the age of six; 5,049 adults over the age of 65; and 13,628 females of reproductive age (15 - 44 years).

In 1997, there were 58,175 military employees and 12,657 civilian employees associated with the base (Naval Base, Norfolk n.d.). NSN supports the largest military population of any base in the world (Naval Station Norfolk n.d.a.). Most military employees spend only 2 to 4 years stationed at the base (Naval Station Norfolk 2000). There are approximately 20 piers, 4,000 buildings, and an airfield on site (CH2MHILL 1999a).

The nearest residences to the base are in the Glenwood Park community, a residential neighborhood of 3,600 people (ATSDR-DHAC 1998a). There are houses in Glenwood Park as close as 200 feet west of the Camp Allen Landfill (Site 1), although a dense woods divides the home from the landfill. Also near the Camp Allen Landfill and Camp Allen Salvage Yard are the Capehart Navy Military Housing Area, the Camp Allen Elementary School (which opened in 1970), and the Camp Elmore U.S. Marine Corps barracks (Baker 1993). While there are several Navy family housing areas near the base, there are only 109 on-base housing units. As of December 2000, there were 92 military personnel and 229 dependents living in on-base housing (Bridges 2000).

Camp Allen Elementary School is the only school within NSN. It is less than 1,000 feet southeast of Site 22, the Camp Allen Salvage Yard (Baker 1993). Other schools within 1 mile of the site include Willoughby Elementary School to the northeast, Northside Middle School to the east, Granby High School to the south, and Sewells Point Elementary School near the southwestern corner of the base.

Access to NSN is restricted to military personnel, civilian employees, and authorized visitors. The base is surrounded by a perimeter fence. People entering the facility must pass through guarded entrance gates. Within base boundaries, the following contaminated sites are fenced: Sites 3, 5, 6, 21, and 22. Also, within the Camp Allen Landfill area, Area B is fenced, but Area A is not (Naval Station Norfolk 2000; Baker 1993).

Natural Resources

NSN elevation ranges from sea level at the northern and western edges to about 15 feet above sea level in the center of the site. Most surface water drains to Mason Creek to the east or to the area formerly occupied by Bousch Creek. The main channel of Bousch Creek was filled and replaced by a network of drainage ditches, channels, and culverts during the development of the installation. Mason Creek and the remnant tributaries to Bousch Creek are tidal and drain to Willoughby Bay, which discharges to the Chesapeake Bay. Some surface water runoff from the base flows to the Elizabeth River (CH2MHILL 1997a). As previously noted, the NSN stormwater drainage system is undergoing comprehensive inspection and rehabilitation. The base has also implemented a program to monitor its discharges to the Hampton Roads Sanitation District (FFA 1999). No drinking water intakes are downstream of the site.

The Elizabeth River hosts a great deal of shipping traffic with extensive industrial activity along its banks. Norfolk Naval Shipyard, the largest naval shipyard in the world, also an NPL site, is located adjacent to the river. Contamination from point sources and runoff resulted in the river being designated a Region of Concern by EPA's Chesapeake Bay Program in 1993. Various cooperative committees studying the river advise against swimming in the river near its shores. However, the river is used for other types of recreation, including boating and fishing in some areas (Alliance for the Chesapeake Bay n.d.; EPA Chesapeake Bay Program 1999; Elizabeth River Project 1996).

Boating, fishing, and crabbing are popular in Willoughby Bay. There are several marinas and numerous piers from which fishing is allowed along the bay. There are several public and community beaches west of the base along the Chesapeake Bay, separated from the Willoughby Bay by Willoughby Spit (LeBleu 1996). There are no designated swimming areas on the Willoughby Bay or the Elizabeth River in the immediate vicinity of NSN (Baker 1993).

Quality Assurance and Quality Control

In preparing this public health assessment, ATSDR reviewed and evaluated information provided in the referenced documents. Documents prepared for the IRP program must meet specific standards for adequate quality assurance and control measures for chain-of-custody procedures, laboratory procedures, and data reporting. The environmental data presented in this public health assessment are from Navy sampling reports, including investigations of the IRP sites, AOCs, and SSAs, as well as sampling of water from drinking fountains and faucets; Virginia Department of Health (VDOH) and Virginia Department of Environmental Quality (VDEQ) databases; EPA reports and databases; and city of Norfolk water quality sampling reports. The limitations of these data have been identified in the associated reports. After evaluating the data, ATSDR determined that the quality of environmental data available in most site-related documents for NSN is adequate to make public health decisions. Data validation was not available for the majority of samples collected from Willoughby Bay, except 1995 samples collected by EPA's Chesapeake Bay Program and 1998 samples collected by VDEQ.

EVALUATION OF ENVIRONMENTAL CONTAMINATION, EXPOSURE PATHWAYS, AND PUBLIC HEALTH IMPLICATIONS

In this section, ATSDR evaluates whether community members have been (past), are (current), or could be (future) exposed to harmful levels of contaminants in the environment. Figure 4 describes the conservative exposure evaluation process used by ATSDR. As the figure indicates, ATSDR considers how people might come into contact with, or be exposed to, contaminated media. Specifically, ATSDR determines whether an exposure could occur through ingestion, dermal (skin) contact with contaminated media (e.g., soil or groundwater), or inhalation of vapors. ATSDR also considers the likely length (duration) and frequency of the exposure.

If exposure was or is possible, ATSDR then considers whether contaminants were or are present at levels that might be harmful to people. ATSDR does this by screening the concentrations of contaminants in an environmental medium (e.g., soil or groundwater) against health-based comparison values (CVs). CVs are contaminant concentrations that health scientists have determined are not likely to cause adverse effects, even when assuming very conservative exposure scenarios. Because CVs are not thresholds of toxicity, environmental levels that exceed comparison values would not necessarily produce adverse health effects. If a contaminant is found in the environment at levels exceeding its corresponding CVs, ATSDR examines potential exposure variables and the toxicology of the contaminant. ATSDR emphasizes that regardless of the level of contamination, *a public health hazard exists only if people come in contact with, or are otherwise exposed to, harmful levels of contaminants in site media.*

After an initial review of potential health hazards at NSN, ATSDR identified the drinking water and biota exposure pathways as requiring further evaluation. Following the strategy outlined above, ATSDR examined whether human exposure to harmful levels of contaminants via these pathways existed in the past, exists now, or could potentially exist in the future. ATSDR summarizes its evaluation of potential exposure pathways in Table 2 and describes it in more detail in the discussion that follows. To acquaint readers with terminology used in this report, a glossary is included as Appendix B. In addition, Appendix C presents the methods and assumptions used to estimate exposures and support some of the report's conclusions.

Concern: Exposure to Off-site Drinking Water

Has contaminated groundwater from Naval Station Norfolk moved off site, and does it impact any municipal or private wells in the vicinity? If so, is there a potential for it to result in adverse health effects?

Conclusions

ATSDR reviewed area hydrogeologic information, available information about wells in the vicinity of NSN, and information about the nature and extent of groundwater contamination to assess the potential for adverse health effects to occur as a result of exposure to off-base drinking water. The city of Norfolk provides drinking water to Norfolk residents and businesses, including NSN, and requires that city water be used where it is available.

Water in the shallow Columbia Aquifer is not considered potable in the vicinity of NSN because it contains high concentrations of iron and manganese and has a low pH. In fact, the city of Norfolk prohibits using wells that draw shallow groundwater to provide drinking water. The only wells that ATSDR identified near the base that draw from this aquifer are in Glenwood Park and are used only for outdoor purposes, such as watering of gardens, not for drinking water. In addition, available information indicates that these wells are not expected to be affected by contamination originating from NSN. The low levels of a few contaminants detected in several wells would be unlikely to result in adverse health effects. Thus, exposure to shallow groundwater poses no public health hazard.

Contamination in the deep Yorktown Aquifer would not be expected to cause adverse health effects because there are no drinking water wells drawing water from this aquifer downgradient of site-related groundwater contamination. Therefore, deep groundwater poses no public health hazard.

Discussion

Hydrogeology

The geologic formation that immediately underlies NSN is approximately 60 feet deep and is known as the Columbia Group. The upper 20 to 40 feet of the formation, consisting of unconsolidated silt and fine sand, holds groundwater and is known as the shallow (or Columbia) aquifer. Hydraulic conductivity in the shallow aquifer is relatively low because groundwater does not flow easily through the silt and fine sand. The depth to the water table is usually less than 8 feet. This aquifer discharges to Mason Creek, the Elizabeth River, and the James River at Willoughby Bay (CH2MHILL 1999a; Kearney 1990).

The lower 20 to 40 feet of the Columbia Group are relatively impermeable and are made up of silt, clay, and sandy clay. Underlying the Columbia Group is the Yorktown Formation, which is approximately 90 to 100 feet thick in this area. There is a clay layer in the upper portion of this formation, and below this layer are moderately coarse sand, gravel, and shell fragments that hold groundwater. The water-bearing zone is known as the Yorktown Aquifer and is semiconfined by the overlying clay layer (CH2MHILL 1999a). Confining beds are thought to be absent in some areas, including the Camp Allen area, allowing groundwater to migrate from the shallow aquifer to the Yorktown Aquifer (Kearney 1990).

Groundwater Use

The city of Norfolk provides drinking water to Norfolk (including NSN), Chesapeake, and Virginia Beach. This water is drawn from the Blackwater River, the Nottoway River, and nine lakes, six of them at least 2.75 miles southeast of the base and the other three more than 15 miles southwest of the base. These surface water sources are sometimes supplemented by four wells drawing deep groundwater. All four wells are more than 5 miles southwest of NSN; three are located in Suffolk, and the other is in Isle of Wight County. Before being distributed, water is treated at either the Moores Bridge or 37th Street water treatment plant (Rosenthal 2001; City of Norfolk 2001). Since 1992, the city of Norfolk has required properties within the city to be connected to the public water supply if they are located on streets where public water supply lines are available. In these areas, alternative water supplies (e.g., private wells) may be used only for heating and cooling, irrigation, and other outdoor uses (Norfolk City Code 1995). Reportedly, a city of Norfolk ordinance also prohibits any use of the shallow aquifer for drinking water due to high concentrations of iron and manganese, as well as a low pH (CLEAN 1999).

In the past, there was no comprehensive requirement for individuals to register their wells with the state, county, or city when they were drilled. However, wells designed to draw more than 300,000 gallons of water per month were required to obtain groundwater withdrawal permits from the VDEQ (Newton 2001). In 1990, a requirement to register all private wells with the Department of Public Health came into effect (Graves 2001). ATSDR contacted VDEQ and the Department of Public Health to request information about recorded wells in the vicinity of the site. Neither agency had records of any residential drinking water wells within 1 mile of the site.

VDEQ records, supplemented by information collected by the Navy, indicate that there are two industrial wells located about ¼ mile southwest of the CD Landfill, east of Hampton Boulevard, which formerly served Global Technology Systems (formerly Sheller-Globe) and three additional wells used by the Lone Star cement plant in its industrial process, located about ½ mile west of the Global Technology Systems wells. VDEQ records also indicate that a well drawing from the deep aquifer was drilled at the Mercury Roller Rink (later Olympic Skateway), at the intersection of Granby Street and Interstate 564, about 1,000 feet southeast of the southeastern corner of NSN. VDEQ did not have any additional information about the use of this well. NSN reports reveal that a well at building MCA-600 drawing from the deep aquifer was used until 1991 for lawn watering. This well, located about 500 feet east of Camp Allen Landfill Area B, was sampled in the 1980s and reportedly did not contain contamination. Finally, there are some wells drawing from the shallow aquifer in the Glenwood Park community, west of Area A of the Camp Allen Landfill, but the water drawn from them is used outdoors and is not used for drinking water. None of these wells are thought to be downgradient of NSN (Baker 1994b, 1995b, 1996b; VDEQ-RS 2000, 2001; Graves 2001).

Nature and Extent of Contamination

ATSDR reviewed available NSN groundwater samples collected on the base and in nearby off-site areas in connection with investigations of IRP sites, AOCs, and SSAs, as well as information about NSN groundwater treatment systems. ATSDR focused on the nature and extent of contamination that has extended or might extend off site and to areas where people live, work or go to school. These data are described in the following two sections, which address shallow groundwater and deep groundwater separately. In some areas, the two aquifers are connected, as the confining layer between them is discontinuous. On-site sampling data are presented in Appendix A.

<u>Shallow Groundwater</u>

The only shallow (Columbia Aquifer) groundwater contamination that is known to extend off site is located in the Camp Allen area. The CD Landfill is unlikely to be the source of off-site groundwater contamination. Shallow groundwater flow near the CD Landfill is generally to the east (and slightly to the south), and the base boundary is more than 1,000 feet to the southwest (CH2MHILL 2001b).

Volatile organic compounds (VOCs) are present near the boundary of NSN in the Camp Allen Landfill Area A. Two areas of groundwater contamination within Area A have been identified and labeled Area A1 and Area A2. Area A1 includes the brig area and the southern portion of Area A, while Area A2 is in the northern part. Figure 5 depicts the Camp Allen area, including Areas A1 and A2. In general, shallow groundwater in Area A flows radially outward from the brig, in the central part of Area A. It flows towards a drainage ditch that begins at the Camp Allen Elementary School and runs just outside of the boundary of Area A, within the NSN property line. Water in this ditch flows northward along the western boundary of Area A, where it is joined in Area A2 by a smaller ditch that runs along the northern portion of the site. The ditches, located between Camp Allen Landfill Area A and the NSN property line, are tidally-influenced and thought to serve as a hydrogeologic boundary between the Camp Allen area and off-site areas to the west. Groundwater flow in the shallow aquifer is relatively low because the aquifer is thin and has a low hydraulic conductivity (Baker 1994b; CH2MHILL 2001b).

Two extraction wells drawing shallow groundwater were installed in Area A2 in the late 1990s as part of the groundwater treatment system. The wells are located south of the smaller drainage ditch. Because groundwater does not flow easily through the silt and fine sand that makes up the shallow aquifer, the extraction wells capture only contaminated groundwater in their immediate vicinity (i.e., within several feet). Few shallow groundwater samples have been analyzed from the monitoring wells north of the extraction wells. One sample collected in 2001 did not contain any VOCs, except a trace of one VOC well below its CV.

A third shallow groundwater extraction well was drilled in Area A1, just west of the brig and east of the larger drainage ditch. This extraction well is no longer in use because shallow and deep groundwater are hydraulically connected in the area (because the confining layer between them is discontinuous) and deep extraction wells can capture shallow groundwater. There are three deep groundwater extraction wells nearby, as well as a deep extraction well about 600 feet further to the south, southeast of the terminus of Glenview Avenue (CH2MHILL 2001b).

Shallow groundwater contamination from the Camp Allen Landfill would not be expected to extend beyond the drainage ditch west of Area A1 because the ditch serves as a hydrogeologic barrier preventing shallow groundwater contamination from moving off site. One off-base monitoring well west of the drainage ditch contained very low levels of several VOCs in 1991 (1 microgram per liter [μg/L] benzene, 1 μg/L tetrachloroethylene [PCE], 1 μg/L toluene, 2 μg/L xylene, 10 μg/L acetone, and 10 μg/L methylene chloride). The methylene chloride concentration exceeds the drinking water CV of 5 μg/L, but this VOC is a possible laboratory contaminant. The benzene concentration also slightly exceeded its CV of 0.6 μg/L. The same well was resampled in 1992 and 1993, and no VOCs were present at measurable concentrations. No samples have been collected from off-site wells drawing from the shallow aquifer in this area since 1993, but a few samples from the deep aquifer are available. Shallow groundwater is hydraulically connected to deep groundwater in the region. Deep groundwater is discussed further in the next section (Baker 1994b, CH2MHILL 2001b, Johnson 2001).

In Camp Allen Area B, there are thought to be several sources of groundwater contamination, in both the northern and southern parts of the site. Shallow aquifer contamination (primarily metals and VOCs that are found in solvents, fuel, and fuel oil) is migrating to the southeast. Southeast of the northern part of Area B is the Camp Elmore Marine Corps Barracks and C Street, which runs perpendicular to the boundary of Area B. South of C Street is the Camp Allen Elementary School. Since 1998, seven extraction wells have been pumping and treating contaminated groundwater southeast of Area B. The lateral extent of the capture zones is less than 800 feet in Area B. Figure 6 depicts Area B and vicinity, as well as the locations of extraction wells and shallow monitoring wells (Baker 1994b, CH2MHILL 2001b).

Table 3 presents the highest levels of VOCs detected at Area B and off site (that is, outside of the IRP site). Fourteen metals have also been detected at concentrations exceeding their drinking water CVs in shallow groundwater near Area B (see Appendix A), but the metals are thought to be present in soil suspended in groundwater, not in the groundwater itself. In addition, north of C Street, the pesticides dieldrin (reaching 0.94 μg/L) and gamma-hexachlorocyclohexane (0.15 μg/L) were detected at concentrations exceeding their CVs (0.002 μg/L and 0.1 μg/L, respectively) (Baker 1994b, c, d; CH2MHILL 1998b, 2000e, 2001b).

Detected levels of most contaminants in shallow groundwater have been higher north of C Street than south of it. VOCs extend as far as a drainage ditch about 150 feet south of the Camp Allen Elementary School, which is believed to serve as a hydrogeologic barrier, as it receives shallow groundwater discharge. Although the drainage ditch is thought to serve as a hydrogeologic barrier to the southward migration of groundwater contamination, 1991 sampling activities revealed shallow groundwater contamination south of the drainage ditch, at the northern end of Bright Street. This area is within the Capehart Military Housing Area, part of which os within NSN. Geoprobe sampling for trichloroethylene (TCE), 1,2-dichloroethene (1,2-DCE), and benzene conducted as part of the remedial investigation (RI) for the Camp Allen Landfill revealed concentrations of TCE reaching 79 μg/L (above the CV of 5 μg/L) and concentrations of 1,2-DCE reaching 36 μg/L (below the CV) in this area in 1991. A seepage area associated with the contamination was identified at that time on the southern bank of the drainage ditch that is south of the Camp Allen Elementary School. The source of the contamination is not known, but it is not thought to be associated with Camp Allen Landfill or Salvage Yard (Baker 1994b, c).

After the contamination was detected, the Navy installed several monitoring wells within and near the Capehart Military Housing Area to better characterize the nature of contamination. In samples collected from two monitoring wells just north of the drainage ditch behind the school, six VOCs have been detected at concentrations exceeding CVs: vinyl chloride (780 μg/L), TCE (510 μg/L), 1,1-dichloroethene (1,1-DCE, 51 μg/L), 1,2-dichloroethane (1,2-DCA, 120 μg/L), total 1,2-DCE (418 μg/L), and benzene (20 μg/L). For the most part, concentrations were highest in samples collected in 1992 and have declined in samples collected in subsequent years. The absence of VOCs in a monitoring well between the drainage ditch and groundwater contamination emanating from Area B of the Camp Allen Landfill indicates that the landfill is not the source of contamination. A shallow aquifer monitoring well south of the drainage ditch did not contain detectable levels of VOCs when it was sampled in 1992 and 2001. The houses in the Capehart Military Housing Area are south of the drainage ditch, and there are no known wells in the area. Shallow groundwater would be expected to migrate away from the houses and towards the drainage ditch to the north. Any shallow groundwater contamination that reaches the deep aquifer is expected to be captured by the deep extraction wells in Camp Allen Area B (Baker 1994b; Johnson 2002; CH2MHILL 1998b, 2000e, 2001b).

<u>Deep Groundwater</u>

At the CD Landfill, deep groundwater in the Yorktown Aquifer is thought to flow (on the basis of data from the Camp Allen Landfill) to the north or northwest. No off-site groundwater samples have been collected near this site. Only one well at the CD Landfill site itself was screened in the deep aquifer, and when it was sampled in 1993, only two metals were detected at concentrations slightly exceeding their CVs: arsenic (detected at 2.8 μg/L, compared to its drinking water CV of 0.02 μg/L) and lead (detected at 16.9 μg/L, compared to its CV of 15 μg/L) (Baker 1995b). These levels, however, might be naturally occurring and would not result in adverse health effects to people with limited exposure to them.

Deep groundwater contamination originating from Camp Allen Landfill Area A extends west and north of the site, in both Area A1 and Area A2. Sampling data suggest that the deep groundwater contamination in Area A2, north of Area A, is about 1,000 feet from the nearest wells, which were used by Global Technology Systems, but are reportedly no longer in use. In the 1980s, when the two wells were still being used for industrial purposes, a deep monitoring well was installed near them to determine if contaminants from the Camp Allen Landfill were affecting these wells. Results from three samples collected from the monitoring well in 1983, 1984, and 1986 did not indicate that contamination originating in the Camp Allen area had reached this area. Only the 1983 sample contained detectable levels of any VOCs. In that sample, methylene chloride was detected at a concentration of 17 μg/L, which exceeds its CV (5 μg/L), and toluene was detected at a concentration of 18 μg/L, less than one-tenth of its CV (200 μg/L). Cadmium (30 μg/L), lead (140 μg/L), and thallium (100 μg/L) were also detected at concentrations exceeding their CVs (2 μg/L, 15 μg/L, and 0.5 μg/L, respectively) in the 1983 and 1986 samples (Pirnie 1988; CH2MHILL 2001b).

VOCs and metals were detected at levels exceeding CVs in the deep aquifer monitoring wells in Area A2 during the RI for the Camp Allen Landfill. In samples north of the site, the metals found at levels exceeding CVs and their maximum detected concentrations were: arsenic (26.7 μg/L, CV = 0.02 μg/L), iron (62,400 μg/L, CV = 11,000 μg/L), lead (15.3 μg/L, CV = 15 μg/L), manganese (1,010 μg/L, CV = 500 μg/L), thallium (6 μg/L, CV = 0.5 μg/L), and vanadium (103 μg/L, CV = 30 μg/L). The VOCs detected at concentrations exceeding CVs in samples collected during the RI and in subsequent available samples collected through 2001 are summarized in Table 4. VOC concentrations have been declining over time.

Currently, VOC contamination also appears to extend approximately 500 to 750 feet west of Area A1. VOCs have been detected in several monitoring wells that draw deep groundwater from locations within Glenwood Park, east of Bousch Creek Avenue, as well as two locations north of these wells. There is an extraction well that pumps and treats contaminated groundwater from the deep aquifer between Area A1 and the drainage ditch to its west, as well as an extraction well just south of the terminus of Beechwood Avenue. There are also two inactive extraction wells located between Area A1 and the drainage ditch. Sampling results indicate that concentrations of VOCs have been declining in this area since 1992, at least in part as a result of the Camp Allen Landfill groundwater treatment system (Baker 1994b, c, d; CH2MHILL 2001b). VOCs detected at concentrations exceeding CVs in locations west of Area A1 are summarized in Table 4.

VOC contamination in the deep aquifer is also present southeast of Camp Allen Landfill Area B. The source of VOCs is thought to be subsurface contamination in Area B in an area where the confining layer between the Columbia and Yorktown Aquifers is absent. The highest levels of VOCs in the deep Yorktown Aquifer have been detected along the southeastern portion of Area B. Three extraction wells east of Area B treat groundwater from the deeper aquifer. VOCs that have been detected southeast of Area B at concentrations exceeding CVs are presented in Table 4. Dieldrin was also detected at a concentration (0.009 μg/L) that exceeded its CV (0.002 μg/L) in an off-site sample collected east of Area B, north of C Street (Baker 1994b, c, d; CH2MHILL 2001b).

Evaluation of Potential Public Health Hazards

Shallow Groundwater

The only wells identified near the site that draw water from the shallow aquifer are in the Glenwood Park community. Water from these wells is used only for watering lawns and other outdoor uses, not for drinking water. Because there is a drainage ditch between the Camp Allen Landfill and the residential area that is thought to serve as a hydrogeologic barrier, and on the basis of one round of sampling, wells in Glenwood Park are not thought to be affected by contamination from the Camp Allen Landfill. Groundwater quality and use in Glenwood Park is discussed in further detail in the "Community Health Concerns" section of this public health assessment. Any past, current, or future exposures to contaminants are not expected to cause adverse health effects because the wells are not used for drinking water, sampling revealed very low levels of VOCs in only a few wells, and the area is not thought to be affected by Camp Allen Landfill groundwater contamination. The small amounts of VOCs detected would not accumulate in any vegetables grown in backyard gardens. Therefore, exposure to shallow groundwater poses no public health hazard.

Deep Groundwater

The only wells drawing from the deep aquifer potentially downgradient of NSN groundwater contamination are used only for industrial purposes. Additionally, these wells are not currently affected by hazardous levels of groundwater contaminants. Sources of deep groundwater contamination are being remediated. Thus, exposure to deep groundwater poses no public health hazard.

Concern: Exposure to Fish and Shellfish from Willoughby Bay

Does exposure to fish and shellfish from Willoughby Bay pose a public health hazard?

Conclusions

ATSDR reviewed all available surface water, sediment, and aquatic biota (i.e., fish and shellfish) samples collected in Willoughby Bay, analyzed from 1971 to 2001. ATSDR also reviewed available information about potential fish and shellfish consumption patterns. ATSDR then estimated the potential doses using very conservative assumptions that would most likely overestimate the levels of actual exposure. On the basis of these calculations, ATSDR concludes that exposures to levels of contaminants detected in samples of fish and shellfish from Willoughby Bay would not be expected to result in adverse health effects. Although data gaps reflecting past seafood consumption patterns and past concentrations of contaminants to which people may have been exposed make it difficult to draw definite conclusions about past exposure, sampling conducted in 2001 by VDEQ indicated that levels of contaminants in fish and shellfish species to which people are exposed do not present a current or future public health hazard. Appendix C provides a detailed explanation of the evaluation process used to make this determination.

Wastewater and stormwater management requirements are expected to reduce contaminant levels reaching the bay over time. Available samples suggest that levels of most contaminants detected at concentrations above screening values are declining, except arsenic and zinc. Finally, ATSDR concurs with the recommendation of EPA's Chesapeake Bay Program for further study of contamination in Willoughby Bay.

Discussion

Willoughby Bay Use

Fishing and crabbing reportedly are popular in Willoughby Bay and the Norfolk area in general. Fish species that are abundant in the bay include croaker and spot, among others. Most edible fish in the bay reportedly migrate within the Chesapeake Bay watershed, if not across an even wider area. This characterization does not apply to eel or shellfish (O'Reilly 2000). Beginning in 1975, people were not allowed to fish in Willoughby Bay due to a ban on fishing in the James River from Richmond to the Hampton Roads Bridge-Tunnel, north of Willoughby Bay. The ban resulted from the illegal dumping of kepone (an insecticide) in the James River in Hopewell, which is more than 50 miles from NSN. The ban on sportfishing was lifted in 1980. Restrictions on the commercial harvesting of individual fish species were lifted, beginning in 1981, and the ban was lifted in its entirety in 1988 (Alliance for the Chesapeake Bay 1995; Barron 2001a). On July 1, 1988, the following fish advisory was issued for the area that had previously been affected by the fishing ban, "Kepone may be hazardous to your health. A fish-eating advisory exists for those who consume fish from these waters on a daily basis" (VDOH-DHHC 1988). ATSDR did not observe any signs publicizing this advisory during its site visits.

Locations from which people fish and crab in the bay include a marina near the southwestern tip of Willoughby Spit and a small pier about ½ mile east of the marina (LeBleu 1996). The Virginia Marine Resources Commission (VMRC) requires people who plan to catch finfish or shellfish in the tidal waters of Virginia to purchase licenses for their gear, which they must renew annually. For certain species, there are restrictions on the minimum size and/or the maximum number an angler may take. In addition to licenses, permits are required to commercially harvest several marine species (including crabs) or to use certain types of gear (VMRC n.d.).

Since 1973, the VMRC has collected data on the number of pounds and the dollar value of the commercial seafood harvest in Willoughby Bay. From 1973 to 1992, reporting by dealers was voluntary. Hence, data are not complete. Since 1993, fishermen have been required to report this information about their catch. The VMRC indicates that between 10,000 and 60,000 pounds of blue crabs from Willoughby Bay have been reported harvested annually since 1976. The 1999 blue crab harvest was almost 45,000 pounds. The fish most commonly commercially harvested from Willoughby Bay, according to VMRC data, is grey seatrout. However, the number of pounds of grey seatrout commercially harvested annually has varied since 1994 from less than 50 pounds to more than 1,200 pounds. In a few years, there have been commercial spot and alewife harvests; the highest number of pounds of spot harvested in a year was about 1,325 in 1996 and of alewife was about 2,250 in 1997 (VMRC 2001).

Shellfishing is prohibited along the entire length of the Elizabeth River and its tributaries, including Willoughby Bay, due to concerns about bacteriological contamination (Virginia Department of Health 1997). This prohibition does not apply to blue crabs. Furthermore, hard clams (also called quahogs) and oysters may be harvested from Willoughby Bay and waters within the shellfish condemnation area if the shellfish are relayed to an uncontaminated location for a minimum of 15 days. That is, shellfish may be collected from Willoughby Bay, moved by parties with permits from the VMRC in approved containers to uncontaminated areas for 15 or more days, then washed and processed for sale (VMRC 2000). According to VMRC data, the annual hard clam harvest from Willoughby Bay has ranged from 700 pounds to 3,300 pounds, except in 1996, when no hard clams were harvested. However, no commercial harvest of oysters from Willoughby Bay has been reported for any year since 1973 (VMRC 2001).

During its 1998 site visit, ATSDR observed several people fishing from the bulkheads (sea wall) near the confluence of Bousch Creek and Willoughby Bay (at the intersection of Aircraft Tow Way and Bellinger). In this area, the Virginia Department of Health had posted signs allowing fishing, but banning shellfish harvesting (ATSDR-DHAC 1998a). Fishing in this area, apparently by civilian employees of the NSN, was also observed in 1995 (Baker 1996a). There reportedly is a fishing pier on the eastern (Willoughby Bay) side of the northwestern tip of the base. Also, the Norfolk Naval Sailing Center rents motorboats, which may be used for fishing in Willoughby Bay, to military personnel and their families (Norfolk Naval Sailing Center 2000).

In 1997, the Navy reportedly opened a park in the northeast corner of the base, opposite the aircraft carrier piers. The park, referred to as "Salt Marsh Park," was designed to manage stormwater, attract wildlife, and provide recreational opportunities, and it includes about 1 acre of wetlands. Military and civilian personnel who fish at the park reportedly can catch fish, including bluefish and flounder, in the lagoon, which opens into Willoughby Bay (Army Corps of Engineers 1998).

Nature and Extent of Contamination

Contaminants from IRP sites, on-base industrial areas, spills, and groundwater contamination from NSN have been transported to Willoughby Bay, since runoff and drainage from much of the base discharges to Bousch Creek and Mason Creek, which both empty into the bay. In the past, industrial wastewater from the base was also discharged to the storm sewer system, which discharged to Willoughby Bay. In the mid-1970s, most of the industrial wastewater was rerouted to the NSN Industrial Wastewater Treatment Plant, which discharges to the Hampton Roads Sanitation District sewage treatment plant. The remaining discharges from the storm sewer system to Willoughby Bay are permitted and monitored (Baker 1993). Prior to the permitting of discharges to Willoughby Bay, contaminants entering the bay were not monitored. Moreover, the levels of contaminants contributed to the bay by other activities at NSN are unknown.

Other potential sources of contamination within Willoughby Bay include petroleum products from boats and ships and creosote from wood preservatives in pilings (Swihart 2000). Storm drains from Willoughby Spit might also discharge to Willoughby Bay. Water quality in the bay is also thought to be significantly influenced by water from Hampton Roads (the confluence of the James and Elizabeth rivers), which is carried into Willoughby Bay by outgoing tides (Boon 2001). Since there are significant sources of contamination in both rivers, the contribution to surface water contamination in Willoughby Bay from NSN, as opposed to other sources, would be difficult to determine. ATSDR also notes that many edible fish in Willoughby Bay reportedly migrate within the Chesapeake Bay watershed, if not across a wider area (O'Reilly 2000).

In 1999, an EPA Chesapeake Bay Program report characterizing the tidal rivers that flow into the Chesapeake Bay designated the lower tidal portion of the James River as an "Area of Emphasis, with special concern for Willoughby Bay." This designation indicates that living resources (including fish and shellfish) in the lower James River and in Willoughby Bay might be affected by chemical contamination, primarily from metals. Laboratory tests showed that surface water and sediment from Willoughby Bay caused adverse effects to living organisms and was more detrimental than surface water and sediment from most of the 46 other stations in the tidal rivers from which samples were drawn. As previously noted, the Chesapeake Bay Program had designated the Elizabeth River a "Region of Concern" in 1993, indicating that it was an area where there was a probable chemical contaminant-related problem (EPA Chesapeake Bay Program 1999).

In order to assess the quality of Willoughby Bay and the potential human health effects of any contamination, ATSDR collected and reviewed all the surface water, sediment, and edible aquatic biota sampling data from the bay that could be located. For initial screening, concentrations of contaminants in biota samples were compared to CVs for fish. Available surface water and sediment data were compared to drinking water and surface soil CVs, respectively, because no surface water or sediment CVs are available. These comparison values are used as a conservative screening method. Recreational exposures to surface water and sediment in Willoughby Bay would occur much less frequently than the long-term daily exposure assumed by the CVs. Moreover, Willoughby Bay is not used for drinking water and incidental ingestion of water from Willoughby Bay would result in exposure doses significantly lower than those assumed by drinking water CVs.

ATSDR identified 18 surface water samples collected from Willoughby Bay between 1972 and 1984, as well as a 1995 sample. Most of the samples were drawn from the center of the mouth of Willoughby Bay, but several were drawn from locations near the eastern end of IRP Site 13, the Past Industrial Wastewater Outfalls. Most of the samples were analyzed for metals, and several metals were detected at concentrations slightly exceeding drinking water CVs in the samples from the mouth of Willoughby Bay (see Table 5). Several of the samples were also analyzed for pesticides, and two of the samples were analyzed for PCBs. Neither pesticides nor PCBs were detected in these samples (EPA Chesapeake Bay Program 1998; STORET 2001).

ATSDR identified 17 sediment sampling events conducted in Willoughby Bay, most of which occurred prior to 1988. Samples were analyzed for polycyclic aromatic hydrocarbons (PAHs), PCBs, selected pesticides, and metals. Several sets of samples were collected along IRP Site 13 (where the highest levels of most contaminants were found). Four samples were collected adjacent to Site 12, an alleged mercury disposal site, and others were collected farther from shore. No pesticides were detected at concentrations above soil CVs. PAHs, PCBs, and metals detected at concentrations exceeding their CVs are listed in Table 5 (Baker 1996a, c; EPA Chesapeake Bay Program 1998; MAIA 1997; STORET 2001; VDEQ-CBP 1981; VDEQ-WDG 1987; VDEQ-WQS 1998).

Two sediment samples and three surface water samples from the lagoon adjacent to Willoughby Bay (now part of Salt Marsh Park) were collected in the mid-1990s. In the sediment samples, benzo(a)pyrene (1.2 milligrams/kilogram [mg/kg]), benzo(b)fluoranthene (2.1 mg/kg), and arsenic (8.6 mg/kg) were present at concentrations exceeding their CVs (0.1 mg/kg, 0.87 mg/kg, and 0.5 mg/kg, respectively). In the surface water samples, three metals were present at concentrations exceeding their CVs: cadmium (7.6 μg/L, CV = 2 μg/L), iron (14,700 μg/L, CV = 11,000 μg/L), and lead (145 μg/L, CV = 15 μg/L) (Baker 1996c).

Over the last 30 years, VDEQ and VDOH's Division of Shellfish Sanitation (VDSS) have collected and analyzed fish and shellfish samples from several locations in Willoughby Bay. In summer 2001, VDEQ conducted a round of sampling during which it analyzed composite samples of blue crab, croaker and spot (edible fish), oyster, and hard clam tissue. VDEQ analyzed composite samples for PAHs, pesticides, PCBs, and selected metals (arsenic, cadmium, chromium, mercury, lead, selenium, thallium, and zinc). Prior to 2001, most fish and shellfish samples had been analyzed for a more limited range of contaminants, and many of the past sampling events were focused on oysters, rather than other seafood species that people are thought to be more likely to consume. The results of all identified fish and shellfish sampling events (from both VDSS and VDEQ) are summarized in Table 6 (EPA Chesapeake Bay Program

1999; STORET LDC 2001; VDEQ-CBP 1987; VDEQ-WQS 1998, 2001; VDOH-DSS 2000).[1] Some of the data are presented below.

Oyster samples (most comprised of 10 individual oysters) have been analyzed for metals by VDSS at least biannually since 1974. These samples are collected south of the eastern end of Willoughby Spit. Results from VDSS oyster samples suggest that cadmium, chromium, and lead levels have decreased over time. Virtually all oyster samples collected since 1985 have contained levels of these metals below 1 mg/kg. (One 1987 sample contained 3.1 mg/kg of cadmium; two 1986 and two 1998 samples contained 1.3 mg/kg, 2.1 mg/kg, 10.3 mg/kg, and 74 mg/kg of chromium, respectively; and a 1990 and 1993 sample each contained 2 mg/kg of lead, while one 1986 and two 1987 samples contained <1.9 mg/kg, <2.5 mg/kg, and <2 mg/kg of lead, respectively.) VDEQ biota samples collected in summer 2001 from the center of Willoughby Bay also contained very low levels of cadmium, chromium, and lead. For the 2001 oyster sample, results were reported as <0.01 mg/kg cadmium, <0.05 mg/kg chromium, and 0.13 mg/kg lead. Levels of these three metals in samples from other seafood species (clams, crabs, and fish) have also been relatively low (VDOH-DSS 2000; VDEQ-WQS 1998, 2001).

Arsenic levels in VDSS samples have ranged from an average of 1.2 mg/kg between 1985 and 1989, to an average of 1.4 mg/kg between 1990 and 1994, to an average of 1.71 between 1995 and 2000. These concentrations are all below levels of public health concern. A 2001 VDEQ oyster sample contained <0.5 mg/kg of arsenic. The 2001 VDEQ samples from other species also contained <0.5 mg/kg of arsenic, as did a 1998 VDEQ spot sample. A 1998 VDEQ crab sample contained 1.1 mg/kg of lead (VDEQ-WQS 1998, 2001). Average copper levels have also consistently been below levels of health concern (reaching only 48 mg/kg in VDSS samples). Zinc levels in Willoughby Bay oysters have ranged from an average detected concentration of zinc was 608 mg/kg in samples collected from 1971 through 1980, to an average of 635 mg/kg in samples collected from 1981 to 1990, to an average of 728 mg/kg in samples collected from 1991 to 2000 (VDOH-DSS 2000). In a 2001 oyster sample, VDEQ measured 208 mg/kg of zinc (VDEQ-WQS 2001). This concentration would not be expected to cause any adverse health effects. Furthermore, there has been no known oyster harvesting in Willoughby Bay since 1972 (VMRC 2001).

Other sampling events include the analysis of sixteen blue crab claw samples (from up to five individual crabs) between 1978 and 1980 by VDEQ for 4,4'-DDE. Between 1971 and 1974 and in 1986 and 1987, VDEQ analyzed several samples from oysters and hard clams for metals, PCBs, selected PAHs, and selected pesticides, as well as two spot samples and a blue crab

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[1] In Spring 2001, ATSDR had recommended (on the basis of the data then available) that VDEQ's summer 2001 biota samples include crabs, fish, clams, and oysters and that these samples be analyzed for organics and metals, including arsenic, thallium, and zinc. These new data have been incorporated into Table 6.

sample for metals. These samples were collected from locations near the eastern end of IRP Site 13. The most recent sampling events were the 1998 collection, by VDEQ, of a blue crab and a composite spot sample near the center of Willoughby Bay (and analyzed them analysis of these samples for PAHs, pesticides, PCBs, and six metals) and the 2001 sampling event previously described (EPA Chesapeake Bay Program 1999; STORET LDC 2001; VDEQ-CBP 1987; VDEQ-WQS 1998, 2001; VDOH-DSS 2000).

Evaluation of Potential Public Health Hazards

Levels of contaminants in Willoughby Bay would be expected to have been highest prior to the mid-1970s, when industrial wastewater from NSN drained directly to Willoughby Bay. The institution of wastewater and stormwater management measures would be expected to result in a decline in levels of contaminants reaching the bay in subsequent years. For the most part, available fish and shellfish samples have shown a decline in contaminant levels over time. VDEQ conducted its most recent round of sediment and biota sampling in summer 2001. In response to ATSDR's recommendations, VDEQ sampled crabs, fish, clams, and oysters. All biota samples were analyzed for organics and metals, including arsenic, thallium, and zinc. (VDEQ-WQS 2001).

To evaluate whether health hazards might be associated with exposure to fish and shellfish, ATSDR estimated potential doses from consuming fish and shellfish using very conservative assumptions that will tend to overestimate the levels of actual exposure. These assumptions, ATSDR's methods, and the estimated doses are further described in Appendix C. The only available samples that reflect past concentrations of zinc in seafood samples other than oysters, which are thought to be harvested from Willoughby Bay, are four samples of crab, clam, and spot, three collected in 1971 and one in 1986. These samples contained levels of zinc that might cause short-term, reversible effects—temporary and reversible gastrointestinal distress or decreases in levels of serum cortisol[2]—under acute exposure scenarios. The small number of samples analyzed 15 to 30 years ago and the limited information on past fish and shellfish consumption patterns are not sufficient for a definitive evaluation of the likelihood that past levels of zinc in fish and shellfish might have caused adverse health effects. On the basis of our calculations using conservative assumptions, ATSDR concludes that, with the exception of the possibly elevated zinc levels, no adverse health effects would be expected to result from exposures to the levels of contaminants detected in fish and shellfish samples from Willoughby

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[2] Cortisol is a hormone produced by the adrenal cortex that plays a role in regulating blood pressure, cardiovascular function, and the body's use of proteins, carbohydrates, and fats. Cortisol levels normally rise and fall during the day and are usually at their highest in the early morning and at their lowest around midnight. Cortisol is also produced in response to stress (either physical or psychological) to help the body deal with stressors, and cortisol levels may increase after meals (MEDLINEplus 2001; Stöppler n.d.).

Bay. In the most recent samples that ATSDR evaluated, only oysters were found to contain zinc levels sufficiently high to cause adverse health effects (VDEQ-WQS 2001). Since there is no known oyster harvest from Willoughby Bay, there is no apparent public health hazard from current or future consumption of Willoughby Bay fish and shellfish. ATSDR concurs with the Chesapeake Bay Program's recommendation for further study of contamination in Willoughby Bay.

COMMUNITY HEALTH CONCERNS

A community relations plan for NSN provides guidance for keeping the community informed about site-related activities and involving the community and other interested parties in the decision-making process for selecting remedial alternatives. Public meetings are held to inform citizens of ongoing remedial activities and to solicit their input. Navy officials also have given community presentations and are available to discuss any concerns that community members have. The public may review site-related documents, including RI reports and correspondence relating to cleanup activities, at a repository at:

Kirn Memorial Branch
Norfolk Public Library
301 East City Hall Avenue
Norfolk, VA 23510
(804) 664-7323

A RAB composed of representatives of the Navy, EPA, the Commonwealth of Virginia, local agencies, and community groups meets regularly to discuss and review ongoing activities at NSN. Two concerns were conveyed to ATSDR during the July 1998 RAB meeting: discolored drinking water from a cooler at an on-base hangar and flooding of a residential yard in Glenwood Park. ATSDR evaluated available information about drinking water from on-base fountains and coolers, which is supplied by the city of Norfolk, and concluded that the discoloration was a short-term occurrence that would not be expected to pose a public health hazard. ATSDR and Navy personnel visited the flooded yard, which was receiving water overflowing from a nearby pond, and agreed that the cause of the flooding should be identified to avert any possible safety hazard. A subsequent assessment indicated that localized flooding occurred in many parts of Norfolk as a result of a major storm that hit the area (Bridges, 2001).

Through meetings, contact with officials and the public, and its review of site documents, ATSDR has identified the following community health concerns:

- *Is the cancer rate in Glenwood Park elevated?*

  According to an analysis of all reported cancer-related deaths and illnesses performed by the Virginia Department of Health's Office of Epidemiology, the death rate from all cancers in Glenwood Park was lower than that in three Norfolk communities studied for comparison. A subsequent analysis of specific cancer deaths, based on names of Glenwood Park residents reported to have had cancer, indicated that there were not an excess number of cancer cases in Glenwood Park, nor were there any "cancer clusters" (i.e., groupings of related cancer incidents) in the neighborhood (Woolard 1990, 1991; Baker 1993).

- *Is groundwater contamination originating from NSN affecting private wells in Glenwood Park?*

Samples from groundwater monitoring wells at the Camp Allen Landfill have contained VOCs at levels exceeding safe drinking water standards. Although homes in Glenwood Park receive drinking water from the city of Norfolk, there are at least 58 homes with private wells used for watering lawns and gardens, filling pools, and/or other outdoor uses. These private residential wells reportedly draw water from the shallow aquifer. The Navy sampled 57 of the wells for VOCs (55 in 1991 and two in 1992) and planned to sample the 58th well, but could not because its pump was broken.

Low levels of VOCs were found in five of the private well samples, but each detection appears to be an isolated incident. Each of the five wells was adjacent to other wells that did not contain detectable levels of VOCs. Two of the 1991 samples contained 2-butanone (also known as methyl ethyl ketone) at concentrations of 10 μg/L and 76 μg/L, respectively. Another sample contained 4 μg/L of acetone, which might have been a laboratory contaminant, since acetone was detected in the blank sample, but not a duplicate sample from the same location. The levels of 2-butanone and acetone that were detected were well below ATSDR's comparison values.

One well sample contained 10 μg/L of PCE, a concentration equal both to the laboratory detection limit for the sample and its drinking water CV. Another sample contained 38 μg/L 1,2-DCA, a concentration that exceeds its CV of 0.4 μg/L (Baker 1994b). PCE is a common byproduct of dry cleaning and industrial metal cleaning or finishing operations. It also can leach into water from the vinyl liners of some types of water pipelines. 1,2-DCA can be found in plastics, rubber and synthetic textile fibers, certain solvents, and is used in making other organics, among other products (EPA 1998).

While the detected concentrations of PCE and 1,2-DCA in two private wells in Glenwood Park exceed certain drinking water screening values, the screening values are based on the assumption that people drink 2 liters of contaminated water per day. Wells in Glenwood Park are not used for drinking water. Thus, residents would be expected to have incidental, infrequent skin contact with contaminated water, which would not be expected to cause adverse health effects at the detected levels.

The Navy has sampled a shallow monitoring well it installed at the eastern end of Glenwood Park, between the terminus of Beechwood Avenue and the drainage ditch to its east. A March 1991 sample from this well contained between 1 and 2 μg/L of total xylenes, toluene, PCE, and benzene. It also contained less than 10 μg/L of acetone and methylene chloride, both detected in the sample blanks and possible laboratory contaminants. Of these detections, only the benzene level and the methylene chloride level exceeded CVs (0.6 μg/L and 5 μg/L, respectively). June 1992 and December 1993 samples from the same location did not contain detectable levels of VOCs (Baker 1994b, c).

Additional samples from monitoring wells drawing shallow groundwater west of the drainage ditch are not available. Any contamination present in Glenwood Park wells is not expected to be attributable to the Camp Allen Landfill because there is a drainage ditch between the landfill and the residences that is thought to serve as a hydrogeologic barrier. Samples from several monitoring wells located between the landfill and Glenwood Park do not show a connection between groundwater contamination in the two areas. Furthermore, shallow and deep groundwater are thought to be hydraulically connected in the area, and concentrations of VOCs in deep monitoring wells in the area have declined since the Camp Allen Landfill groundwater treatment system began operating. Therefore, the groundwater treatment system appears to be successfully drawing any VOCs from the shallow aquifer to the deeper aquifer and eastward towards the extraction wells (Baker 1994b, 1995a; CH2MHILL 2001b; Johnson 2002).

- *Does discolored drinking water from a drinking water cooler at one of the base hangars or metals in other on-base sources of drinking water pose a health hazard?*

At the July 1998 RAB meeting that ATSDR attended, a base employee inquired about discolored drinking water at building SP-31, a hangar. Base personnel, like other water system users, have sometimes observed discolored water coming from water coolers or faucets. Drinking water is provided to the base from the city of Norfolk's 37th Street Plant. Water samples are analyzed regularly at the plant before the water is distributed, in compliance with the Safe Drinking Water Act (SDWA). No violations of SDWA standards occurred in 1999 or 2000 (City of Norfolk 2001).

If the Navy Public Works Center receives any complaints of discolored drinking water, it advises people to first flush the water in their taps. If the problem persists, Public Works personnel investigate and address the source of the problem (Din 2000). Similarly, when the city of Norfolk's Department of Utilities is notified of discolored water in city lines, it identifies the source of the problem and addresses it.

According to the city of Norfolk's Division of Water Quality, water discoloration commonly results from particles resting on the bottom of pipes being picked up by water traveling through pipes and carried along with the water. This might occur after a water line disturbance, such as water line maintenance, or any other circumstance that causes water to travel through pipes at a higher velocity than normal. Discolored drinking water typically is not considered to pose a health risk, but the city of Norfolk recommends that users not drink temporarily discolored water until it is clear again (City of Norfolk 2001; EPA 1992).

Lead, copper, and other metals present in water distribution systems can leach into drinking water. Several measures have been implemented to reduce the potential for exposure to metals in drinking water. Since approximately 1990, the city of Norfolk has added zinc orthophosphate to the water it distributes. This compound creates a protective film along the walls of pipes, reducing the potential for corrosion (which allows metals to leach into water) (Land 2000). In the early 1990s, the Navy implemented a program to measure lead levels in a sample from each on-base water fountain or cooler located in a "priority area" (base housing, food preparation area, or medical facility). The program required that measures be taken to address any elevated lead levels found, such as the replacement of the affected fountains (Office of the Chief of Naval Operations 1994). In addition, old water mains throughout the base that might have contained lead joints are being replaced over time (Din 2000).

The Navy provided ATSDR with the results of lead sampling conducted at drinking fountains at base hangars. Fifty-four of the 60 samples ATSDR reviewed contained levels of lead below 15 µg/L, EPA's action level and ATSDR's drinking water CV. The other six samples were collected from hangars LP-14 and LP-4. Lead levels exceeding the CV were detected in four of the ten 1994 samples from LP-14 (17 µg/L, 72 µg/L, and 160 µg/L in samples collected on the same day from one fountain and 38 µg/L in a sample from another fountain). When the fountain where elevated levels were detected in three samples was resampled the following day, the lead level was only 12 µg/L. Samples collected in 1989 from fountains in the building had not contained lead levels exceeding the CV. LP-14 was demolished in 1996. The detections of lead in the water from LP-14 fountains are unlikely to have resulted in adverse health effects, as exposures to base employees would have been limited. Two of 12 samples collected from fountains at LP-4 in 1989 and 1991 contained levels of lead less than three times the CV. These levels would not be expected to cause adverse health effects under the expected exposure scenarios (Heaney 1999).

No sampling data from fountains or coolers at hangar SP-31, about which the employee had expressed concern in July 1998, were provided to ATSDR. In addition, the Public Works Department does not have records of any complaints received about fountains or coolers at the hangar in question around that time (Navy Public Works Center 2000). Thus, ATSDR expects that the discolored drinking water present in building SP-31 was a short-term occurrence and did not pose a public health hazard. As noted earlier in this document, the Navy and the city of Norfolk take measures to protect the quality of drinking water provided to base employees and their families.

The Navy also provided ATSDR with data from sampling it conducted in compliance with the EPA's Lead and Copper Rule, which requires that the concentration of each metal exceed the appropriate EPA action level in less than 10% of samples analyzed. This sampling program targets faucets in Navy facilities, which would not be expected to be common sources of drinking water, not drinking fountains or coolers. Taps from 60 locations throughout the base were sampled biannually from 1992 to 1998; during each sampling event, levels of lead and copper exceeded EPA action levels in fewer than 10% of samples, in compliance with the Lead and Copper Rule. Thus, annual monitoring has been reduced to 30 locations. NSN's 1999 and 2000 sampling also complied with the rule. However, since 1992, there have been sporadic instances in which lead and copper levels in individual samples have exceeded CVs (Navy Public Works Center 2000; NSN n.d.b.; VDOH-OWP 2000). In most locations, these instances were isolated, and any exposures to elevated levels of lead and copper in water from these faucets would be sufficiently infrequent that they would not result in adverse health effects.

The only building where lead or copper levels seem to regularly exceeded CVs (15 μg/L for lead and 1,300 μg/L for copper) is Building Z-103. The lead level in the first sample collected from the faucet, in 1992, was 114 μg/L. Two 1993 samples contained 35 μg/L and 65 μg/L lead, respectively. In subsequent samples collected biannually from 1994 to 1998, samples collected between January and June contained levels of lead below the CV, but samples collected between July and December contained levels of lead ranging from 16 μg/L to 34 μg/L. While no samples were collected from this faucet in 1999, a sample collected in the second half of 2000 contained only 2 μg/L lead. Copper levels measured in this location have consistently been below the CV.

While lead and copper levels exceeded CVs from 1993 to 1996 at the location sampled in the Marine Corps Exchange (MC-1), concentrations measured in samples collected since 1996 have been below levels of health concern. The levels of lead and copper did not exceed CVs in one sample collected in 1992. Lead levels ranged from 78 to 105 μg/L in four 1993 and 1994 samples, dropped to 14 μg/L in a winter 1995 sample, rose to 208 μg/L in a summer 1995 sample, then dropped to 36 μg/L in winter 1996 and 5 μg/L in summer 1996. Copper levels in samples from the faucet at MC-1 exceeded the CV in 7 of 8 samples collected from 1993 to 1996. Concentrations during the eight sampling events were as follows: 3,450 μg/L; 1,680 μg/L; 20 μg/L; 3,060 μg/L; 6,000 μg/L; 3,600 μg/L; 1,700 μg/L; and 2,620 μg/L. A sample collected each year from 1997 to 2000 did not contain concentrations of either metal at levels of health concern (Navy Public Works Center 2000; NSN n.d.b.; VDOH-OWP 2000).

Faucets are not expected to be regular, frequent sources of drinking water at NSN. Under short-term and infrequent exposure scenarios, the detected levels of lead and copper would not be expected to cause adverse health effects. However, as a precautionary measure, ATSDR recommends that the Navy verify that the faucet sampled at Z-103 is not commonly used for drinking water. If the Navy determines that it is, ATSDR recommends that it be resampled. If levels of lead exceed CVs, ATSDR recommends that the Navy take appropriate measures to ensure that people are not exposed to these concentrations, either by remediating the sources of lead and/or copper or ensuring that the faucet is not used for drinking water.

- *Are on-base residents exposed to lead-based paint or asbestos?*

During its 1998 site visit, ATSDR investigated the ways in which the Navy protects on-base residents from exposure to lead-based paint and asbestos. In accordance with its lead and asbestos management plans, the Navy has surveyed its housing units and identified those that contain lead-based paint or asbestos. Educational materials about exposure to lead paint are distributed to people moving into base housing. The Navy has affixed labels to crawl spaces and attics in base housing warning residents that these areas may contain asbestos and that residents should avoid breathing airborne asbestos fibers (Bridges 2000). Pediatricians serving the children of base personnel follow the Centers for Disease Control and Prevention's recommendations for screening the blood lead levels of young children. The results of 1999 and available 2000 blood lead screening did not show any children living in on-base housing with elevated blood lead levels (Olesen 2000). Because the Navy takes measures to ensure that there is no exposure to friable asbestos in housing and provides information to on-base residents about the potential risks of exposures to lead-based paint, ATSDR expects any residential exposures to be limited.

■ *What are the public health implications of exposure to emissions from former incinerators, open burning areas, boilers, and/or smelters?*

Several activities at NSN formerly generated air emissions. Air emissions were not regulated prior to the 1970s, and little information is available about these past sources (Johnson 2000). Site-related documents indicate that smelting and incineration at the Camp Allen Salvage Yard, incineration and open burning at the Camp Allen Landfill, burning of salvage fuel and other waste in a boiler, and aluminum smelting in the naval magazine (NM) area of the Naval Air Station were formerly conducted. ATSDR did not identify any ambient air samples collected at the times these activities were under way. Therefore, ATSDR focused its review on available information about the emissions sources.

In the southeast corner of the Camp Allen Salvage Yard, a smelter operated for about 30 years in the vicinity of Building CA220. Aluminum and lead were smelted, and debris from the smelter was usually transported to Area A of the Camp Allen Landfill for disposal. A small incinerator, reportedly used to burn insulation from copper wiring for reuse, was adjacent to the smelter (Baker 1994a). Because it has been some years since the smelter and incinerator operated, no additional information about the operations of these facilities is available (CLEAN 1999). During the preliminary assessment/site investigation for the Camp Allen Salvage Yard, one soil sampling location was selected to assess potential soil contamination at the former smelter and incinerator site. Neither the surface soil sample (0–6 inches) nor the subsurface soil sample (30–36 inches) contained detectable levels of most contaminants. Arsenic, detected at 1.9 mg/kg in surface soil and 3.8 mg/kg in subsurface soil, was the only contaminant detected at concentrations exceeding its soil CV (0.5 mg/kg). However, the arsenic concentrations detected in these samples were lower than concentrations measured in most other samples from the Salvage Yard area collected from corresponding depths, as were concentrations of other metals (Baker 1994a; CLEAN 1999).

An incinerator built in the southern portion of Camp Allen Landfill Area A in the mid-1940s operated until the mid-1960s. It was used to burn a variety of combustible wastes. Materials too bulky for the incinerator were burned in Area A. No records offering more detailed information about these activities are available. Incineration and open burning were relatively common practices at that time and were not regulated (Baker 1994c). Soil samples from Area A of the Camp Allen Landfill in 1992 contained three metals at concentrations exceeding CVs: arsenic (70 mg/kg, CV = 0.5 mg/kg), cadmium (89 mg/kg, CV = 10 mg/kg), and lead (683 mg/kg, CV = 400 mg/kg). Some samples also contained Aroclor-1260 (0.42 mg/kg, CV = 0.32 mg/kg) and benzo(a)pyrene (0.31 mg/kg, CV = 0.1 mg/kg). Aroclor-1260, a PCB, is unlikely to be associated with air emissions from burning activities. Benzo(a)pyrene was only detected after the landfill removal action and is a common contaminant that can be attributable to vehicle emissions. The elevated metals levels could be from past incineration activities (or from soil from nearby borrow pits used for landfill capping) (Baker 1994b), although there is no way to confirm this and the soil data do not permit estimates of past air emissions.

Documents generated during investigations of the NM Slag Pile indicate it received slag in the 1950s and 1960s that had been generated by aluminum smelting operations conducted in the NM area of the Naval Air Station (CH2MHILL 1997b). ATSDR did not identify any additional information about these operations. A unit known as the Salvage Fuel Boiler Plant operated from 1967 until 1986 in Building Z-309, northwest of the intersection of Admiral Taussig Boulevard and Virginia Avenue. It generated steam by burning salvage fuel, supplemented with residential and office waste. Although the plant ceased operating in September 1986, apparently due to violations of its state of Virginia air permit, it was reportedly upgraded in 1976 with electrostatic precipitators to meet air pollution control standards. AOC 1 includes the area where ash from the boiler was managed, as well as an adjacent area where oils and lubricants were stored. AOC 1 has been investigated by the Navy and determined not to require further action. Appendix A lists the metals and PAHs detected in surface soil in this area. These data, however, do not provide information about the concentrations of pollutants present in air when the boiler was operating (Kearney 1990; CH2MHILL 1999a).

The Navy has quantified current on-base sources of air emissions and applied for an operating permit for these sources pursuant to the Clean Air Act (CAA) (Naval Base Norfolk Environmental Department 1998). CAA permits are designed to minimize emissions and protect public health. The public will have the opportunity to review and comment on the draft permit before it is finalized.

People who are or were near operating sources of air emissions might be or have been exposed to airborne contaminants as they disperse, but the nature and extent of these exposures cannot be quantified. ATSDR has not identified any evidence of health concerns related to air emissions of base personnel or their families, or of members of the surrounding community. In the absence of data characterizing the amounts of contaminants released, ambient air concentrations to which people were or are exposed, and exposure frequency and duration, ATSDR cannot assess the public health implications of exposures to air emissions. In the future, emissions will be limited by pollution control equipment and the requirements of the CAA permit, and these measures are expected to keep emissions to levels that would not be of health concern.

- *Do exposures to children in the vicinity of the Camp Allen Elementary School pose a public health hazard?*

In 1992, as part of the RI for the Camp Allen Landfill, soil, surface water, sediment, and air samples were collected in the vicinity of the Camp Allen Elementary School. Levels of environmental contaminants detected in this area are not expected to result in adverse public health effects.

Contaminants detected during these sampling events at concentrations exceeding CVs are presented in Table 7. Three soil samples collected northwest of the school were analyzed for metals. Arsenic, cadmium, and chromium were present at concentrations that exceeded CVs. The Navy reported that the detected concentrations of arsenic and chromium were probably naturally occurring and does not plan any follow-up sampling.

RI sampling activities included the collection of two surface water samples and three sediment samples from a drainage ditch near the school. The drainage ditch is not large enough to be used for swimming or fishing and goes dry periodically. Two sampling locations were used, one about 200 feet south of the school and the other more than 1,000 feet west of the school. The surface water sample collected south of the school contained only arsenic at a concentration exceeding its CV. The other surface water sample contained arsenic at a slightly higher concentration, as well as antimony, iron, lead, and manganese at concentrations exceeding their CVs. Two shallow and one deep sediment samples (collected from the same locations as the surface water samples) were analyzed for metals. In these samples, only arsenic was detected at concentrations exceeding its CVs (Baker 1994b, 1995a).

The Camp Allen Elementary School is partially fenced (Baker 1994c). Soil sampling locations were between the school and Area B of the Camp Allen Landfill. Children would not be expected to have regular and extended exposures to soil in these areas. Exposures to surface water and sediment in the drainage ditch would be expected to be infrequent and of short duration. ATSDR expects that infrequent exposures of short duration to the detected concentrations of metals in soil, surface water, and sediment would not result in adverse health effects.

Fifteen air samples were collected within the school in 1992. The only contaminants present at concentrations exceeding air CVs were benzene and hexachlorobutadiene. Benzene was present in all 15 samples from the school and from 15 samples collected near the landfill, at concentrations ranging from 0.4 $\mu g/m^3$ to 0.7 $\mu g/m^3$. Hexachlorobutadiene was present at a concentration of 0.3 $\mu g/m^3$ in four samples (from three locations). The same concentration of the VOC also was detected in four of 15 ambient air samples collected in 1992 near the Camp Allen Landfill (Baker 1994b, 1995a).

Tobacco smoke, motor vehicle exhaust, and industrial emissions are sources of benzene, as well as vapors from products that contain benzene, including paints, glues, and detergents. Hexachlorobutadiene is produced from the synthesis of certain chlorinated hydrocarbons and is used in the production of rubber compounds. The maximum detected concentrations of benzene and hexachlorobutadiene in air samples were lower than levels reported in the scientific literature as causing adverse health effects. In addition, background levels of benzene are commonly more than five times higher than levels detected at the Camp Allen Elementary School (ATSDR 1994a, 1997).

At the time the air samples were collected, groundwater contamination was not thought to extend beneath the elementary school. If any future groundwater monitoring data indicate that substantial groundwater contamination is migrating underneath the school or other areas where people live, work, or go to school, ATSDR recommends the Navy evaluate the appropriateness of collecting additional indoor air samples.

If people have other concerns to share with ATSDR, they can call us at 1-888-42-ATSDR or write to: Chief, Program Evaluation, Records, and Information Services Branch, Agency for Toxic Substances and Disease Registry, 1600 Clifton Road (E-56), Atlanta, GA 30333.

ATSDR CHILD HEALTH INITIATIVE

ATSDR recognizes that infants and children might be more sensitive to exposures than adults in communities with contamination in their water, soil, air, or food. This sensitivity is a result of a number of factors. Children are more likely to be exposed to soil or surface water contamination because they play outdoors and often bring food into contaminated areas. Children are shorter than adults, which means they can breathe dust, soil, and any vapors close to the ground. Children also are smaller, resulting in higher doses of chemical exposure per body weight. The developing body systems of children can sustain permanent damage if toxic exposures occur during critical growth stages. Most importantly, children depend completely on adults for risk identification and management decisions, housing decisions, and access to medical care. Therefore, ATSDR is committed to evaluating their special interest at sites such as NSN, as part of the ATSDR Child Health Initiative.

ATSDR has attempted to identify populations of children in the vicinity of NSN and any completed exposure pathways to these children. As previously noted, approximately 6,700 children under the age of 6 live within 1 mile of NSN. There are no on-site childcare facilities, but the Camp Allen Elementary School is within NSN, directly southeast of Camp Allen Landfill Area B. Several other schools are located near the base.

ATSDR has evaluated the likelihood of children being exposed to contamination at NSN at levels of health concern. *On the basis of available data, ATSDR has not identified site contamination that would pose a health hazard for children.*

ATSDR has not identified any private wells used for drinking water near the site that draw from either the shallow or the deep aquifer that might be affected by groundwater contamination. ATSDR will evaluate new groundwater and drinking water data as they are made available to us.

Swimming in the Elizabeth River near shore is not recommended, and swimming in Willoughby Bay is thought to be uncommon, as the only nearby public beaches are located on the Chesapeake Bay. Because any exposures to surface water and sediment in the marine waters adjacent to the base would be limited, such exposures pose no apparent public health hazard to children. ATSDR evaluated child exposures to fish and shellfish harvested from Willoughby Bay. We reviewed available data on concentrations of contaminants present in fish and shellfish, available information on fish and shellfish consumption patterns, and toxicological literature about the potential for health effects from exposure to the contaminants detected. There has been no known harvest of oysters from Willoughby Bay since 1972, and past data reflecting contaminant concentrations in species other than oysters are limited. Furthermore, site-specific data about children's seafood consumption patterns is not available. However, available data indicate that temporary decreases in serum cortisol levels and short-term reversible gastrointestinal distress might have been possible in the past, if oysters with these levels of zinc were consumed. It should be stressed that these effects would have been short-term and reversible. ATSDR evaluated the potential for health effects to occur currently and in the future, based on the 2001 sampling results. Our evaluation concluded that current and future exposures to zinc from consuming fish and shellfish from Willoughby Bay would not be expected to cause any adverse health effects, since the only species that contained zinc levels sufficiently high to possibly cause these short-term, reversible health effects was the oyster, and oyster harvesting is not thought to occur. Appendix C provides a detailed explanation of ATSDR's evaluation process.

Children might occasionally come into contact with surface water and sediment contamination in drainage ditches that are affected by site-related contamination, such as the one south of the Camp Allen Elementary School. These drainage ways, however, are too small to permit swimming or fishing. ATSDR reviewed contaminant levels in drainage ditches where children might be exposed and concluded that these contaminants would not be expected to pose a public health hazard to children because of the limited exposures that would be anticipated. Children who live in on-base housing or who trespass on the base might access soil and debris at certain areas of the site. However, ATSDR did not find evidence that children are regularly accessing the sites under investigation within NSN. Children might have incidental contact with off-site soil, but the levels of contaminants detected in off-site samples are too low to cause adverse health effects in such situations. Therefore, soil contamination associated with NSN is not expected to pose a health hazard to children.

CONCLUSIONS

On the basis of its evaluation of available information, ATSDR has reached the following conclusions:

1. The city of Norfolk provides drinking water to most of Norfolk and regularly samples the water it distributes. The only known private wells near the base drawing from the shallow aquifer do not provide drinking water and are not expected to be affected by contamination originating from NSN. The low levels of contaminants detected in a few shallow wells used for nonpotable purposes, including use in watering backyard vegetable gardens, would be unlikely to result in adverse health effects. Thus, shallow groundwater poses *no public health hazard.* There are no known off-site drinking water wells drawing water from the deep aquifer downgradient of site-related contamination, so deep groundwater poses *no public health hazard.*

2. NSN receives its drinking water from the city of Norfolk. Both the city and the Navy take measures to reduce the potential for exposure to metals that might leach into water from pipes. In addition, the Navy has sampled for lead and copper at a number of on-base fountains and faucets. In most locations, detected levels of the two metals were below screening values or, in a few cases, above screening values but below levels that would be expected to result in adverse health effects under expected exposure scenarios. However, samples from one NSN faucet in a work area (at Z-103) have shown a pattern of elevated levels of lead. Because the faucet is not a drinking fountain it is unlikely that it is commonly used for drinking water. Under infrequent exposure scenarios, the detected levels of lead would not be expected to cause adverse health effects. Thus, exposure to metals leaching into on-base water from pipes poses *no apparent public health hazard.*

3. Available indoor air samples collected in 1992 near the Camp Allen Landfill to assess the potential for exposures to VOCs migrating via groundwater did not contain levels of contaminants of potential health concern. For this reason, the potential for VOC migration from Camp Allen Landfill is considered *no apparent public health hazard.*

4. Hard clams, blue crabs, and fish are recreationally and commercially harvested from Willoughby Bay, but oyster consumption is thought to be infrequent, if it occurs at all, as the oyster population in the bay is very limited. ATSDR reviewed available fish and shellfish tissue samples, which were limited for some contaminants.

The small number of samples that reflect past contaminant concentrations is not sufficient to provide for a definitive evaluation of past exposure. Some samples from Willoughby Bay (mostly samples collected more than 15 years ago, but also a 2001 oyster sample) contained zinc at levels that could result in the possible occurrence of minor, temporary and reversible gastrointestinal distress, particularly in the event of exposure to oysters. However, any exposure to zinc would not be expected to cause any lasting adverse health effects. On the basis of available samples reflecting current contaminant concentrations and expected consumption patterns, no adverse health effects would be expected from exposure to other contaminants. Thus, ATSDR concludes that current or future consumption of marine biota from Willoughby Bay poses *no apparent public health hazard* and past exposure posed an *indeterminate public health hazard.*

PUBLIC HEALTH ACTION PLAN

The Public Health Action Plan (PHAP) for NSN contains a description of actions taken, planned, and recommended to be taken by ATSDR, the Navy, VDOH, VDEQ, and EPA subsequent to the completion of this public health assessment. The purpose of the PHAP is to ensure that this public health assessment not only identifies potential and ongoing public health hazards, but also to provide a plan of action designed to mitigate and prevent adverse human health effects resulting from exposure to hazardous substances in the environment. The public health actions that are completed, ongoing or planned, and recommended are listed below.

Completed Actions:

1. The Navy identified possible sources of contamination during numerous investigations.

2. Because the Glenwood Park residential area is located adjacent to the Camp Allen Landfill and residents use private wells for nonpotable purposes, the Navy sampled 57 wells in the neighborhood, revealing several isolated cases of low-level VOC contamination.

3. In 1990 and 1991, the Virginia Department of Health's Office of Epidemiology reviewed area cancer incidence data and cancer data submitted by the citizens of Glenwood Park, which did not reveal any evidence of elevated cancer morbidity (i.e., cancer cases) or cancer mortality in the Glenwood Park community.

4. In response to an ATSDR recommendation, the Navy repaired the fence around the Camp Allen Salvage Yard in October 1998.

5. The Navy conducted corrective or remedial actions at Sites 3, 4, 11, 15, 17, 18, 19, 20, and 22, as well as SSA 2, in the 1980s and at Sites 1, 2, 4, 5, 6, 11, 19, 21, and 22, as well as SSA 3 and AOC 1, in the 1990s.

6. An RI and feasibility study (FS) have been completed for Sites 1, 2, 3, 4, 6, and 20, and an RI and risk assessment report was completed for Site 22. Decision documents have been finalized for Sites 1 and 6, and a ROD has been drafted for Site 2.

7. The Navy fully investigated contamination at 12 IRP sites and 4 AOCs, remediated them as appropriate, and does not plan to take any further action at the sites (Sites 4, 7, 8, 9, 10, 11, 12, 13, 16, 17, 18, 19, and 21, as well as AOCs 1, 3, 7, and 8). The Navy also plans not to take any further action at Sites 14 and 15, referring them to its underground storage tank (UST) program.

8. EPA and VDEQ have analyzed surface water, sediment, fish, and shellfish samples from Willoughby Bay. In summer 2002, VDEQ released the results of a summer 2001 sampling event during which it collected samples of sediment and biota from Willoughby Bay and analyzed them for organics and metals.

9. The Navy conducts lead and asbestos abatement programs at NSN and provides information to residents about the potential hazards caused by any Navy-owned residences affected by lead-based paint.

Ongoing or Planned Actions

1. The Navy operates groundwater treatment systems at Sites 1, 3, and 20 and conducts long-term monitoring at these sites, as well as at Sites 2 and 6.

2. Investigations at SSAs 1, 2, and 4, as well as AOCs 2, 4, 5, and 6, are under way.

3. A Proposed Remedial Action Plan is being developed for Site 22.

4. Closeout Reports are being drafted for SSA 3 (to be closed under the UST program) and Site 5.

5. The Virginia Department of Health's Department of Shellfish Sanitation collects a sample of 10 oysters from Willoughby Bay biannually and analyzes it for six metals.

6. The Virginia Department of Environmental Quality will continue to monitor contaminant levels in marine biota in Willoughby Bay.

Recommended Actions

1. ATSDR recommends that the Navy verify that the faucet sampled at Z-103 is not commonly used for drinking water. If the Navy determines that the faucet is used for drinking water, it should be resampled. If levels of lead exceed CVs, the Navy should take appropriate measures to ensure that people are not exposed to these levels of contaminants.

2. If any future groundwater monitoring data indicate that substantial groundwater contamination is migrating beneath any areas where people live, work, or go to school, ATSDR recommends the Navy evaluate the appropriateness of collecting additional indoor air samples.

3. ATSDR concurs with a Chesapeake Bay Program recommendation for further study of contamination in Willoughby Bay.

REFERENCES

Alliance for the Chesapeake Bay. 1995. James River Fact Sheet. http://www.acb-online.org/factshts/james.htm. 1995.

Alliance for the Chesapeake Bay. n.d. Elizabeth River Fact Sheet. http://www.acb-oneline.org/factshts/eliz.htm. Undated.

Army Corps of Engineers. 1998. U.S. Army Corps of Engineers. Norfolk Creates Shoreside Refuge. Engineer Update 22:1. http://www.hq.usace.army.mil/cepa/pubs/jan98/story5.htm. January 1998.

Agency for Toxic Substances and Disease Registry (ATSDR). 1994a. Toxicological Profile for Hexachlorobutadiene. May 1994.

ATSDR. 1994b. Toxicological Profile for Zinc (Update). May 1994.

ATSDR. 1997. Toxicological Profile for Benzene (Update). September 1997.

Agency for Toxic Substances and Disease Registry, Division of Health Assessment and Consultation (ATSDR-DHAC). 1998a. Naval Base Norfolk Site Summary. August 1998.

ATSDR-DHAC. 1998b. Agency for Toxic Substances and Disease Registry, Division of Health Assessment and Consultation. Health Consultation/Site Summary: USN Norfolk Naval Base—Camp Allen (a/k/a Norfolk Naval Base [Sewells Point Naval Complex]). October 29, 1998.

Baker Environmental, Inc. (Baker). 1993. Final Community Relations Plan, Naval Base Norfolk, Norfolk, Virginia. Prepared for Atlantic Division, Naval Facilities Engineering Command, Norfolk, Virginia. May 27, 1993.

Baker. 1994a. Final Preliminary Assessment/Site Inspection Report, Camp Allen Salvage Yard, Naval Base Norfolk, Norfolk, Virginia. Prepared for Atlantic Division, Naval Facilities Engineering Command, Norfolk, Virginia. May 27, 1994.

Baker. 1994b. Final Remedial Investigation Report, Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia. Prepared for Atlantic Division, Naval Facilities Engineering Command, Norfolk, Virginia. July 14, 1994.

Baker. 1994c. Final Feasibility Study, Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia. Prepared for Atlantic Division, Naval Facilities Engineering Command, Norfolk, Virginia. November 17, 1994.

Baker. 1994d. Final Executive Summary, Remedial Investigation, Baseline Risk Assessment, and Feasibility Study, Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia. Prepared for Atlantic Division, Naval Facilities Engineering Command, Norfolk, Virginia. November 17, 1994.

Baker. 1995a. Baseline Risk Assessment, Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia, Revised Final. Prepared for Atlantic Division, Naval Facilities Engineering Command, Norfolk, Virginia. February 1995.

Baker. 1995b. Final Remedial Investigation, CD Landfill, Naval Base, Norfolk, Norfolk, Virginia. Prepared for Atlantic Division, Naval Facilities Engineering Command, Norfolk, Virginia. December 21, 1995.

Baker. 1996a. Final Relative Risk Ranking System Data Collection Sampling and Analysis Report, Naval Base, Norfolk, Virginia. January 9, 1996.

Baker. 1996b. Final Remedial Investigation Report and Baseline Risk Assessment, Building LP-20 Site, Naval Base, Norfolk, Virginia. September 13, 1996.

Baker. 1996c. Draft Relative Risk Ranking System Data Collection Sampling and Analysis Report, Phase II, Naval Base, Norfolk, Virginia. December 9, 1996.

Barron, A. 2001a. Personal communication with Alex Barron, Virginia Department of Environmental Quality, Water Quality Standards, Fish Tissue Monitoring Program. January 10, 2001.

Barron, A. 2001b. Personal communication with Alex Barron, Virginia Department of Environmental Quality, Water Quality Standards, Fish Tissue Monitoring Program. May 17, 2001.

Barron, A. 2001c. Written communication from Alex Barron, Virginia Department of Environmental Quality, Water Quality Standards, Fish Tissue Monitoring Program. September 7, 2001.

Boon, J. 2001. Personal communication with Dr. John Boon, Physical Oceanographer, Virginia Institute of Marine Science. January 3, 2001.

Bridges, W. 2000. Personal communication with Wendy Bridges, Industrial Hygienist, Environmental Programs Directorate, Naval Environmental Health Center. December 8, 2000.

Bridges, W. 2001. Written communcation from Wendy Bridges,

Industrial Hygienist, Environmental Programs Directorate,
Naval Environmental Health Center. Septmebr 7, 2001.
CH2MHILL. 1997a. Final Site Management Plan: Naval Base, Norfolk; Norfolk, Virginia. March 1997.

CH2MHILL. 1997b. Remedial Investigation of the NM Slag Pile, Naval Base, Norfolk, Virginia, Draft. September 1997.

CH2MHILL. 1998a. Final Feasibility Study, NM Slag Pile, Naval Base, Norfolk; Norfolk, Virginia. September 1998.

CH2MHILL. 1998b. Long-Term Monitoring Plans for Four Sites at Naval Base Norfolk: Revised Draft Long-Term Monitoring Plan for Camp Allen Landfill. September 1998.

CH2MHILL. 1999a. Draft Final 1999–2000 Site Management Plan, Naval Base, Norfolk; Norfolk, Virginia. January 1999.

CH2MHILL. 1999b. Technical Memorandum Number One, Long-Term Monitoring Plans for Four Sites at Naval Base Norfolk, Norfolk, Virginia. May 11, 1999.

CH2MHILL. 2000a. Draft Final Record of Decision, NM Slag Pile, Naval Station Norfolk,. Norfolk, Virginia. January 2000.

CH2MHILL. 2000b. Revised Draft Solid Waste Management Unit (SWMU) Close-Out Reports: SWMUs 2, 3, 40, 41, and 42, Naval Station Norfolk, Norfolk, Virginia. February 2000.

CH2MHILL. 2000c. Revised Draft Solid Waste Management Unit (SWMU) Streamlined Risk Assessments: SWMUs 28, 32, 33, 34, and 35, Naval Station Norfolk, Norfolk, Virginia. February 2000.

CH2MHILL. 2000d. Draft Final 2000–2001 Site Management Plan, Naval Station Norfolk, Norfolk, Virginia. July 2000.

CH2MHILL. 2000e. Final Annual Long-Term Monitoring Report for Three Sites, Naval Station Norfolk, Norfolk, Virginia. October 2000.

CH2MHILL. 2001a. Final First Year Post-Closure Monitoring Report for the CD Landfill, Naval Station Norfolk, Norfolk, Virginia. February 2001.

CH2MHILL. 2001b. Final Technical Memorandum Number Two, Long-Term Monitoring of Four Sites, March 2001–April 2001, Naval Station Norfolk, Norfolk, Virginia. November 2001.

CH2MHILL. 2001c. Close-Out Report For Installation Restoration (IR) Sites: Site 7—Inert Chemical Landfill, Site 8—Asbestos Landfill, Site 12—Mercury Disposal Site, and Site 17—Building SDA 215, Naval Station Norfolk, Norfolk, Virginia. March 2001.

City of Norfolk. 2001. City of Norfolk, Division of Water Quality. Current Water Quality Reports. http://www.city.norfolk.va.us/utilities/quality/index.html. Last updated April 25, 2001.

CLEAN. 1999. Comprehensive Long-Term Environmental Action Navy. Final Remedial Investigation/Risk Assessment Report for Camp Allen Salvage Yard, Naval Station Norfolk, Norfolk, Virginia. November 9, 1999.

Din, W. 2000a. Personal communication with Wilkie Din, Environmental Engineer, Navy Public Works Center. December 7, 2000.

EDAW. 1995. EDAW, Inc.; Patton Harris Rust & Associates, pc; and Shriver & Holland Associates. Naval Base Norfolk: 2010 Land Use Plan. Prepared for Atlantic Division, Naval Facilities Engineering Command, Norfolk, Virginia. August 1995.

Elizabeth River Project. 1996. Elizabeth River Restoration: A Watershed Action Plan to Restore the Elizabeth River, Leadership Review Draft. April 26, 1996.

Environmental Science & Engineering, Inc. 1994. Final Remedial Investigation Report, Q Area Drum Storage Yard, Norfolk Naval Base, Norfolk, Virginia. April 1994.

U.S. Environmental Protection Agency (EPA). 1992. Secondary Drinking Water Regulations: Guidance for Nuisance Chemicals. EPA 810/K-92-001. http://www.epa.gov/safewater/consumer/2ndstandards.html. July 1992.

EPA. 1998. Drinking Water and Health: Contaminant Specific Fact Sheets for Consumers. http://www.epa.gov/OGWDW/dwh/c-voc.html. Fact sheets on Tetrachloroethylene and 1,2-Dichloroethane revised in 1998.

EPA. 1999. General Site Information: Norfolk Naval Base. http://www.epa.gov/reg3hwmd/super/norfolk/pad.htm. Last updated April 1999.

EPA Chesapeake Bay Program. 1998. Ambient Toxicity Testing in Chesapeake Bay: Year 5 Report. EPA 903/R/98/008. February 1998.

EPA Chesapeake Bay Program. 1999. Targeting Toxics: A Characterization Report. A Tool for Directing Management and Monitoring Actions in the Chesapeake Bay's Tidal Rivers. June 1999. http://www.chesapeakebay.net/pubs/792.pdf and http://www.chesapeakebay.net/info/toxdata.html.

FFA. 1999. Federal Facilities Agreement between EPA Region III and the U.S. Department of the Navy. Admin. Docket No. III-FCA-CERC-015. February 18, 1999.

Graves, J. 2001. Personal communication with Jeffrey Graves, Norfolk Department of Public Health. April 27, 2001.

Groundwater Technology Government Systems. 1994. Report of Findings and Recommendations, Light Non-aqueous Phase Liquid Plume Delineation Recovery Well Placement, Piers 2-12 and 20-25, Naval Base, Norfolk, Virginia. October 20, 1994.

Heaney, S. 1999. Letter from Sean S. Heaney, Director, UST/Wastewater Division, Naval Base Norfolk, to Brian Kaplan, ATSDR, concerning attached lead analysis results from sampling drinking fountains within base hangars. January 14, 1999.

Johnson, W. 2000. Personal communication with Winoma Johnson, Atlantic Division, Naval Facilities Engineering Command. December 14, 2000.

Johnson, W. 2001. Written communication from Winoma Johnson, Atlantic Division, Naval Facilities Engineering Command. September 7, 2001.

Johnson, W. 2002. Written communication from Winoma Johnson, Atlantic Division, Naval Facilities Engineering Command. January 24, 2002.

Kearney. 1990. A.T. Kearney, Inc. Phase I Preliminary Review of the Norfolk Naval Base, Norfolk, Virginia. July 1990.

Land, V. 2000. Personal communication with Vernon Land, Chief, Division of Water Quality, Department of Utilities, City of Norfolk. December 19, 2000.

LANTDIV. 2000. Atlantic Division, Naval Facilities Engineering Command. Naval Station Norfolk: IR Site Tour, 4/14/00. April 14, 2000.

LeBleu, W.M. 1996. Fishing on the River James. Virginia Sportsman 1(1). Formerly available from http://www.announce.com/vanet/vasport6.htm. September 1996.

MAIA. 1997. EPA: Mid-Atlantic Integrated Assessment (MAIA). MAIA Estuaries 1997–98 Data. Samples from Willoughby Bay from August 25, 1997. http://www.epa.gov/emap/maia/html/data/estuary/9798/. Last updated 01/04/01.

Malcolm Pirnie. 1998. Installation Restoration Program Remedial Investigation—Interim Report, Naval Base, Norfolk, Virginia. March 1998.

MEDLINEplus. 2001. MEDLINEplus Health Information: A Service of the National Library of Medicine. Medical Encyclopedia: Cortisol Level. http://www.nlm.nih.gov/medlineplus/ency/article/003693.htm. Last Updated 3 October 2001.

Naval Base, Norfolk. n.d. The Navy in Hampton Roads: A Statistical Report for Fiscal Year 1997 (1 October–30 September). Undated.

Naval Base Norfolk Environmental Department. 1998. Commonwealth of Virginia, Title V Operating Permit Application for Naval Base, Norfolk, Norfolk, Virginia. Prepared by Commander, Naval Base Norfolk Environmental Department, Navy Facilities Engineering Atlantic Division Command, and Roy F. Weston, Inc. May 1998.

Naval Station Norfolk. 2000. Site Visit conducted by ATSDR. May 8 to 10, 2000.

Naval Station Norfolk. n.d.a. History of Naval Station Norfolk. http://naval-station.norfolk.va.us/INFO/ABOUT_US/HISTORY/history.html. Undated.

Naval Station Norfolk. n.d.b. Lead and Copper Sampling for Norfolk Naval Base, Rounds 1–11 (1992–1998). Undated.

Navy Public Works Center. 2000. Lead and Copper Sampling Results for Norfolk Naval Base, Rounds 12 (Jul–Dec 1998) and 14 (Jun–Dec 2000). Transmitted by facsimile by Wilkie Din, Environmental Engineer, Navy Public Works Center. December 7, 2000.

Newton, V. 2001. Personal communication with Virginia Newton, Virginia Department of Environmental Quality, Remediation Section. January 10, 2001.

NOAA. 1997. National Oceanic and Atmospheric Administration. Waste Site Reviews—Virginia: USN Norfolk Naval Base (Reviewed 1997); CERCLIS No. VA6170061463. 1997.

Norfolk City Code. 1995. Code of the City of Norfolk, Virginia. Chapter 46.1-5. Adopted September 8, 1992, and amended July 25, 1995.

Norfolk Naval Sailing Center. 2000. Norfolk Naval Sailing Center: Boating Area. http://www.people.virginia.edu/~cwk6r/rentalarea.htm. March 2000.

Office of the Chief of Naval Operations. 1994. Office of the Chief of Naval Operations, Department of the Navy. Environmental and Natural Resources Program Manual. November 1, 1994.

Olesen, M. 2000. Written communications from Commander Mark C. Olesen, Director, Health, Safety, and Environmental Services Directorate, Naval Medical Center Portsmouth. June 16 and December 19, 2000.

O'Reilly, R. 2000. Personal communication with Robert O'Reilly, Fisheries Management Division, Virginia Marine Resources Commission. December 18, 2000.

Rosenthal, D. 2001. Personal communication with David Rosenthal, Reservoir Manager, City of Norfolk. April 26, 2001.

Sparks, B. and P. Rakowski. n.d. Navy Polychlorinated Biphenyl Fire/Explosion Incidents. Barbara Sparks, Naval Facilities Engineering Command, and Paul Rakowski, Atlantic Division, Naval Facilities Engineering Command. Undated.

Stöppler, M. C., M.D. n.d. Cortisol: The "Stress Hormone." http://stress.about.com/library/weekly/aa012901a.htm. Undated.

STORET. 2001. EPA Storage and Retrieval (STORET) database. Query for Willoughby Bay data collected by VDEQ performed by Roger E. Stewart, Virginia Department of Environmental Quality, Office of Water Quality Assessment and Planning, January 11, 2001.

STORET LDC. 2001. EPA Storage and Retrieval (STORET) database, Legacy Data Center. Query for Willoughby Bay samples based on latitude and longitude. April 13, 2001.

Swihart, G. 2000. Personal communication with Gary Swihart, Project Leader, Office of Fishery Assistance, U.S. Fish and Wildlife Service. December 7, 2000.

Versar, Inc. 1990. Remedial Investigation/Feasibility Study Report for Buildings V-60 and V-90, Naval Aviation Depot, Norfolk, Virginia, Final. January 23, 1990.

Versar, Inc. 1991. Site Risk and Remediation Assessment Report for the Naval Piers 1-25, Norfolk Naval Base, Norfolk, Virginia. June 19, 1991.

Versar, Inc. 1993. Corrective Action Plan: Piers 2 through 12 and 20 through 22, Norfolk Naval Base, Norfolk, Virginia. February 4, 1993.

Virginia Department of Environmental Quality, Chesapeake Bay Program (VDEQ-CBP). 1981. Analytical data for April 25, 1981, sediment sample from Willoughby Bay. Provided by Mark Richards. April 3, 2001.

VDEQ-CBP. 1987. Analytical data for July 17, 1986, and July 22, 1987, hard clam and oyster samples from Sewells Point Naval Complex sampling stations in Willoughby Bay. Provided by Mark Richards. April 17, 2001.

Virginia Department of Environmental Quality, Remediation Section (VDEQ-RS). 2000. Locations of registered wells within approximately 1 mile of Naval Station Norfolk. Provided by Virginia Newton. December 18, 2000.

VDEQ-RS. 2001. Water well completion reports for certain registered wells within approximately 1 mile of Naval Station Norfolk. Provided by Virginia Newton. April 26, 2001.

Virginia Department of Environmental Quality, Water Division General (VDEQ-WDG). 1987. Water Division General, 1985– . July 22, 1987, sediment samples reported in the Chesapeake Bay Program's "Targeting Toxics" report (EPA Chesapeake Bay Program 1999). http://www.chesapeakebay.net/info/toxdata.html.

Virginia Department of Environmental Quality, Water Quality Standards (VDEQ-WQS). 1998. Analytical data from June 1998 samples (sediment, spot, and blue crab) from Willoughby Bay. Provided by facsimile by Alex Barron. January 10, 2001.

Virginia Department of Environmental Quality, Water Quality Standards (VDEQ-WQS). 2001. Analytical data from July and August 2001 samples (hard shell clam, oyster, blue crab, spot, and croaker) from Willoughby Bay. Provided by Alex Barron. June 20, 2002.

Virginia Department of Health. 1997. Notice and Description of Shellfish Area Condemnation Number 7, Hampton Roads. May 1, 1997.

Virginia Department of Health, Division of Health Hazards Control (VDOH-DHHC). 1988. Fishing Restrictions and Health Advisories in Effect for Virginia Rivers. Effective July 1, 1988. http://www.VDH.state.va.us/HHControl/fishing_advisories.htm.

Virginia Department of Health, Division of Shellfish Sanitation (VDOH-DSS). 2000. Metals Monitoring of Oysters, 1974–2000.

Virginia Department of Heath, Office of Water Programs (VDOH-OWP). 2000. Letter from Ernest G. Johnson, Jr., Assistance District Engineer, to Sean S. Heaney, Director, Technical Support Division, Regional Environmental Group, Navy Public Works Center, with attached results of September 1999 Lead and Copper Sampling (Round 13).

Virginia Marine Resources Commission (VMRC). n.d. Fisheries Management Division. http://www.state.va.us/mrc/page1f.htm. Undated.

VMRC. 2000. Regulation 4VAC 20-310-10 et seq., Pertaining to the Relaying of Shellfish. Effective May 15, 2000.

VMRC. 2001. Willoughby Bay Harvest Data (1973–1999). Provided by Stephanie Iverson, Data Supervisor, Fisheries Management Division. January 10, 2001.

Woolard, C.D. 1990. Memorandum from C. Diane Woolard, M.P.H., Senior Epidemiologist, Virginia Department of Health to Valerie Stallings, M.D., M.P.H., Director, Norfolk City Health District, attaching assessment of cancer in various sections of Norfolk. September 14, 1990.

Woolard, C.D. 1991. Memorandum from C. Diane Woolard, M.P.H., Senior Epidemiologist, Virginia Department of Health to Valerie Stallings, M.D., M.P.H., Director, Norfolk City Health District, re: Cancer in Glenwood Park. July 15, 1991.

TABLES

TABLE 1. Summary of Naval Station Norfolk Site Screening Areas and Areas of Concern

Designation under FFA	Name	Original Designation
SSA 1	Q-72 Sandblast Area	SWMU 4
SSA 2	V-28 Waste Pit	SWMU 6
SSA 3	Fire-fighting School	SWMU 8
SSA 4	NM-37 Area	SWMUs 12 and 16
AOC 1	Building Z-309	SWMUs 2 and 3
AOC 2	Marine Air Cargo Area	SWMUs 9 and 10
AOC 3	CEP Area	SWMUs 28, 32, 33, 34, 35, and 42
AOC 4	Q-50 PWC Accumulation Area	SWMU 14
AOC 5	CD Area Behind Compost Yard	SWMU 38
AOC 6	Open Dump and Disposal Area at Boundary of Camp Allen Landfill	SWMU 39
AOC 7	MCA-603 Pits	SWMU 40
AOC 8	Disposal Area, CA-99 Golf Course	SWMU 41

Source: CH2MHILL 2000d

Abbreviations:
AOC area of concern
FFA federal facilities agreement
SSA site screening area
SWMU solid waste management unit

TABLE 2. Evaluation of Potential Exposure Pathways

Pathway Name	Exposure Pathway Elements					Time of Exposure	Comments
	Source of Contamination	Environmental Medium	Point of Exposure	Route of Exposure	Exposed Population		
On-site drinking water	Operations and waste management practices at NSN	Groundwater	NSN taps	Ingestion Inhalation Dermal contact	NSN employees, residents, and visitors	Past Current Future	**Past/Current/Future:** Drinking water is provided by the city of Norfolk, which does not draw water from sources in the vicinity of NSN. The water is treated and sampled regularly. Samples from one faucet at NSN have shown a pattern of elevated levels of lead. Infrequent exposures to the detected concentrations would not be expected to result in adverse health effects. Thus, this exposure pathway poses no apparent public health hazard. As a precautionary measure, ATSDR recommends the Navy verify whether this tap is commonly used for drinking water and, if it is, resample it. If contaminant levels continue to exceed CVs, ATSDR recommends that measures be taken to ensure people are not exposed to these levels of contaminants.
Off-site drinking water	Operations and waste management practices at NSN	Groundwater	Private drinking water wells	Ingestion Inhalation Dermal contact	Any off-site water users served by water lines that intersect groundwater contamination	Past Current Future	**Past/Current/Future:** The city of Norfolk requires that buildings in Norfolk use public water for drinking water if it is available. Most or all nearby locations are served by public water. The only identified wells drawing from shallow groundwater near the site are in Glenwood Park and are not used for drinking water. The low levels of VOCs detected in a few of these wells are not expected to result in adverse health effects. Thus, shallow groundwater poses no public health hazard. There are no known drinking water wells drawing from the deep aquifer downgradient of site-related groundwater contamination. Therefore, deep groundwater poses no public health hazard.

TABLE 2. Evaluation of Potential Exposure Pathways (continued)

Pathway Name	Exposure Pathway Elements					Time of Exposure	Comments
	Source of Contamination	Environmental Medium	Point of Exposure	Route of Exposure	Exposed Population		
Air	Volatilization of VOCs from groundwater and past sources of air emissions	Air	Locations above groundwater contamination or downwind of past sources of air emissions	Inhalation	NSN and nearby residents and visitors, NSN employees	Past Current Future	**Past:** 1992 indoor air samples collected near the Camp Allen Landfill did not contain levels of VOCs of potential health concern. **Current/Future:** NSN has applied for an operating permit for on-site sources of emissions pursuant to the Clean Air Act. Emissions limits are expected to be set at levels protective of public health. If future sampling data indicate that substantial groundwater contamination is migrating underneath areas where people live, work, or go to school, ATSDR recommends the Navy evaluate the appropriateness of collecting additional indoor air samples. Because insufficient data are available to quantify current and future exposures to air contaminants, ATSDR cannot evaluate their potential public health implications.
Soil	Operations and waste management practices at NSN	Soil	Soil on site and near the site potentially affected by site-related contamination (e.g., near the Camp Allen Elementary School)	Ingestion Dermal contact	NSN residents and trespassers, children at the Camp Allen Elementary School	Past Current Future	**Past/Current/Future:** There is no public access to NSN. In a few areas, off-site soil might have been impacted by site-related contamination through deposition of airborne contaminants or transport of contaminated soil (e.g., use of soil from disposal areas for fill). Public exposures to off-site soil and base resident or trespasser exposures to on-site soil would be incidental and of short duration. As contaminant levels in soil to which people might be exposed are too low to cause adverse health effects under limited exposure scenarios, soil poses no apparent public health hazard.

TABLE 2. Evaluation of Potential Exposure Pathways (continued)

Pathway Name	Exposure Pathway Elements					Time of Exposure	Comments
	Source of Contamination	Environmental Medium	Point of Exposure	Route of Exposure	Exposed Population		
Surface water and sediment	Operations and waste management practices at NSN, as well as off-site sources	Surface water and sediment	Surface water on site or near the site potentially affected by site-related contamination	Ingestion Dermal contact	NSN residents and trespassers, recreational users of off-site surface water	Past Current Future	**Past/Current/Future:** Public access to the base is not allowed. Drainage ditches that extend off site are not large enough for swimming. Thus, any public exposures to off-site surface water and sediment potentially affected by site-related contamination, as well as any exposures to base residents or trespassers to on-site surface water and sediment, would be expected to be incidental and infrequent. Limited exposures to the detected levels of contaminants would not be expected to result in adverse health effects. Thus, surface water and sediment pose no apparent public health hazard.
Fish and shellfish from Willoughby Bay	Operations and waste management practices at NSN, as well as off-site sources	Biota	Willoughby Bay	Ingestion	Consumers of fish and shellfish harvested from Willoughby Bay	Past Current Future	**Past:** On the basis of available data reflecting concentrations of contaminants present in fish and shellfish, available information about fish and shellfish consumption patterns, and toxicological literature about the potential for health effects from exposure to the detected contaminants, consumption of fish and shellfish from Willoughby Bay is not expected to result in any adverse health effects, except possibly short-term effects—temporary gastrointestinal distress or decreases in levels of serum cortisol (a hormone produced in response to stress)—from acute exposures to elevated zinc levels. Thus, past consumption of marine biota from Willoughby Bay posed an indeterminate public health hazard. **Current/Future:** On the basis of available data describing recent contaminant levels and current consumption patterns, current and future consumption of marine biota from Willoughby Bay pose no apparent health hazard.

TABLE 2. Evaluation of Potential Exposure Pathways (continued)

Abbreviations:

ATSDR = Agency for Toxic Substances and Disease Registry;
CV = comparison value
NSN = Naval Station Norfolk
VOC = volatile organic compound

TABLE 3. Volatile Organic Compounds Detected in Shallow Groundwater at Concentrations Exceeding Comparison Values, Camp Allen Landfill Area B

Contaminant	Area B, on-site			Area B, off-site			CV (μg/L)	Type of CV
	Maximum detected concentration (μg/L)	Location of maximum	Year of maximum	Maximum detected concentration (μg/L)	Location of maximum	Year of maximum		
Acetone	8,300	GW-4	1991	210	B-MW3A	1991	1000	child RMEG
Benzene	390	GW-4	1991	1,200	B-MW3A	1991	0.6	CREG
Carbon tetrachloride	<7	B-MW2A	2001	3.4	B-MW3A	2000	0.3	CREG
Chlorobenzene	1	B-MW7	1991	110	B-MW1	1991	100	LTHA
Chloroethane	16	GW-5	1991	<250	B-MW1, B-MW3A	1991	3.6	RBC-C
1,2-Dichloroethane	74	GW-4	1983	520	B-MW3A	1991	0.4	CREG
1,1-Dichloroethene	170	GW-5	1983	180	B-MW3A	1991	0.06	CREG
1,2-Dichloroethene	340	GW-4	1983	3,900	B-MW11A	1997	70	LTHA
4-Methyl-2-pentanone	2,100	GW-4	1991	250	B-MW11A	1991	140	RBC-N
Methylene chloride	24,000	GW-4	1983	170	B-MW11A	1991	5	CREG
Tetrachloroethylene	10	B-MW2A	1992	48	B-MW3A	1991	10	LTHA
Toluene	290	GW-4	1984	<120	B-MW11A	1992	200	child i-EMEG
Trichloroethylene	640	GW-4	1983	2,100	B-MW3A	1991	5	MCL
Trichlorofluoromethane	2,300	GW-4	1983	840	B-MW3A	1993	2000	LTHA
Vinyl chloride	79	GW-4	1983	5,100	B-MW11A	1999	0.03	CREG

Sources: Baker 1994b, c; CH2MHILL 1998b, 2000e, 2001b

Abbreviations: CREG = cancer risk evaluation guide; CV = comparison value; i-EMEG = environmental media evaluation guide, intermediate exposure; LTHA = lifetime health advisory; MCL = maximum contaminant level; RBC-C = risk-based concentration, carcinogenic effects; RBC-N = risk-based concentration, noncarcinogenic effects; RMEG = reference dose media evaluation guide; μg/L = micrograms/liter

TABLE 4. Volatile Organic Compounds Detected in Deep Groundwater at Concentrations Exceeding Comparison Values, Camp Allen Landfill, Off-site Samples

Contaminant	Maximum detected concentration (µg/L)	CV (µg/L)	Type of CV
Samples collected north of Area A2			
Benzene	50	0.6	CREG
1,2-Dichloroethane	44	0.4	CREG
1,1-Dichloroethene	930	0.06	CREG
1,2-Dichloroethene	540	70	LTHA
Trichloroethylene	170	5	MCL
Vinyl chloride	240	0.03	CREG
Samples collected west of Area A1			
Benzene	3	0.6	CREG
1,2-Dichloroethene	220	0.4	CREG
Chloromethane	99	2.1	RBC-C
Trichloroethylene	10.5	5	MCL
Vinyl chloride	260	0.03	CREG
Samples collected east of Area B			
Benzene	1,100	0.6	CREG
1,1-Dichloroethene	130	0.06	CREG
1,2-Dichloroethane	900	0.4	CREG
1,2-Dichloroethene	3,900	70	LTHA
Methylene chloride	7	5	CREG
Trichloroethylene	1,900	5	MCL
Vinyl chloride	3,000	0.03	CREG

Sources: Baker 1994b, c; CH2MHILL 1998b, 2000e, 2001b

Notes:
Methylene chloride is considered a possible laboratory contaminant.

Abbreviations:
CREG = cancer risk evaluation guide
CV = comparison value
LTHA = lifetime health advisory
MCL = maximum contaminant level
RBC-C = risk-based concentration, carcinogenic effects
g/L = micrograms/liter

TABLE 5. Contaminants Detected in Surface Water and Sediment Samples from Willoughby Bay at Concentrations Exceeding Comparison Values

Contaminant	Maximum detected concentration	Unit	CV	Type of CV
Surface water samples				
Arsenic	2	μg/L	0.02	CREG
Chromium	40	μg/L	30	child RMEG, Cr VI
Lead	40	μg/L	15	EPA Action Level
Nickel	120	μg/L	100	LTHA
Sediment samples				
Benzo(a)pyrene	6.992	mg/kg	0.1	CREG
Benzo(a)anthracene	6.811	mg/kg	0.87	RBC-C
Indeno(1,2,3-cd)pyrene	4.243	mg/kg	0.87	RBC-C
Polychlorinated biphenyls	2.692	mg/kg	0.4	CREG
Arsenic	26	mg/kg	0.5	CREG
Cadmium	12.7	mg/kg	10	child c-EMEG
Chromium	207	mg/kg	200	child RMEG, Cr VI
Iron	54,800	mg/kg	23,000	RBC-N

Sources: Baker 1996a, c; EPA Chesapeake Bay Program 1998; MAIA 1997; STORET 2001; VDEQ-CBP 1981; VDEQ-WDG 1987; VDEQ-WQS 1998

Abbreviations:
CREG = cancer risk evaluation guide
CV = comparison value
c-EMEG = environmental media evaluation guide, chronic exposure
LTHA = lifetime health advisory
mg/kg = milligrams/kilogram
RBC-C = risk-based concentration, carcinogenic effects
RBC-N = risk-based concentration, noncarcinogenic effects
RMEG = reference dose media evaluation guide
μg/L = micrograms/liter

TABLE 6. Summary of Contaminants that Exceed Risk-Based Concentrations in Fish and Shellfish Samples from Willoughby Bay

Contaminant	Species	Range of Detections (mg/kg, wet weight)	Frequency of Detection	Date of Maximum Detection	Location of Maximum Detection	RBC (mg/kg, wet weight)	Number of Samples > RBC
Benzo(a)pyrene	blue crab	0.00019 - 0.00187	2/2	6/16/98	C	0.00043	1
	clam	0.00042 - 0.032*	2/2	7/16/86	A		1
	oyster	0.00109	1/1	8/30/01	C		1
	spot	0.00057	1/1	6/16/98	C		1
Benzo(a)anthracene	oyster	0.01759 - 0.032*	2/2	07/22/87	A	0.0043	2
	clam	0.00107 - 0.018*	2/2	7/16/86	A		1
	blue crab	0.00017 - <0.01	1/2	6/16/98	C		0
	croaker	0.00006	1/1	7/23/01	C		0
	spot	0.00013 - 0.00014	2/2	6/16/98	C		0
Benzo(b)fluoranthene	oyster	0.01473	1/1	8/30/01	C	0.0043	1
	blue crab	0.00021	1/2	7/23/01	C		0
	clam	0.00137	1/1	8/30/01	C		0
	spot	0.00025	1/1	6/16/98	C		0
Dibenz(a,h)anthracene	spot	0.00047	1/1	6/16/98	C	0.00043	1
	blue crab	0.00022	1/1	6/16/98	C		0
	oyster	0.00018	1/1	8/30/01	C		0
4,4'-DDD	blue crab	0.0013 - 0.020	2/2	6/22/79	A	0.013	1
	spot	0.00091	1/1	6/16/98	C		0
	croaker	0.0015	1/1	7/23/01	C		0
4,4'-DDE	blue crab	0.00191 - 0.040	18/18	08/29/78	A	0.0093	16
	oyster	0.0057 - 0.017*	2/2	07/22/87	A		1
	croaker	0.0049	1/1	7/23/01	C		0
	clam	0.0013	1/1	8/30/01	C		0
	spot	0.00214 - 0.0082	2/2	7/23/01	C		0
4,4'-DDT	blue crab	0.007 - 0.010	1/1	4/24/79	A	0.0093	1
	croaker	0.0003	1/1	7/23/01	C		0
	oyster	0.0002	1/1	8/30/01	C		0
	clam	0.0001	1/1	8/30/01	C		0
Heptachlor epoxide	blue crab	0.00059	1/1	7/23/01	C	0.00035	1
	clam	0.00004	1/1	8/30/01	C		0
	oyster	0.00013	1/1	8/30/01	C		0
	spot	0.00025	1/1	7/23/01	C		0
PCBs	oyster	0.004 - 0.062*	25/25	07/22/87	A	0.0016	25
	clam	0.002 - 0.01243	4/4	7/23/01	C		4
	blue crab	0.0146 - 0.01697	2/2	7/23/01	C		2
	spot	0.0121 - 0.05798	2/2	7/23/01	C		2
	croaker	0.03690	1/1	7/23/01	C		1

TABLE 6. Summary of Contaminants that Exceed Risk-Based Concentrations in Fish and Shellfish Samples from Willoughby Bay (continued)

Contaminant	Species	Range of Detections (mg/kg, wet weight)	Frequency of Detection	Date of Maximum Detection	Location of Maximum Detection	RBC (mg/kg, wet weight)	Number of Samples > RBC
Arsenic	oyster clam blue crab croaker spot	<0.5 - 3.0 <0.5 - 2.5 <0.5 - 1.1 <0.5 <0.5	30/32 1/2 1/2 0/1 0/2	10/28/94 7/16/86 6/16/98 7/23/01 6/16/98	B A C C C	0.0021	30 1 1 0 0
Cadmium	oyster spot clam blue crab croaker	<0.1 - 6.06 <0.01 - 0.019 <0.01 - <0.2 <0.01 <0.01	43/62 1/2 0/2 0/2 0/1	3/3/73 6/16/98 7/16/86 6/16/98 7/23/01	A C A C C	1.4	22 1 0 0 0
Chromium	oyster spot blue crab clam croaker	<0.05 - 74 <0.05 - 5.05 <0.05 - 3.33 <0.05 - <0.2 <0.05	10/32 2/4 1/3 0/2 0/1	4/21/88 7/29/71 7/29/71 7/16/86 7/23/01	B A A A C	4.1 Cr VI 2000 Cr III	2 1 0 0 0
Lead	blue crab clam croaker spot oyster	<0.1 - 6.19 0.13 <0.1 <0.1 - 2.52 0.10 - 2	1/3 1/1 0/1 2/4 10/32	7/29/71 8/30/01 7/23/01 7/29/71 10/30/90, 4/16/93	A C C A B	Not Available	N/A N/A N/A N/A N/A
Mercury	blue crab croaker oyster spot clam	<0.01 - 0.49 <0.01 <0.01 <0.01 - 0.034 <0.01 - <0.02	2/3 0/1 0/1 1/2 0/2	7/29/71 7/23/01 8/30/01 6/16/98 7/16/86	A C C C A	0.14	1 0 0 0 0
Thallium	clam blue crab croaker oyster spot	<0.3 - 2 <0.3 <0.3 <0.3 <0.3	1/2 0/1 0/1 0/1 0/1	7/16/86 7/23/01 7/23/01 8/30/01 7/23/01	A C C C C	0.11	1 0 0 0 0
Zinc	oyster spot blue crab clam croaker	208 - 1,440 5.1 - 124 22 - 64.8 8.4 - 38 4.7	62/62 3/3 2/2 2/2 1/1	10/28/94 7/29/71 7/29/71 7/16/86 7/23/01	B A A A C	410	58 0 0 0 0

Sources: EPA Chesapeake Bay Program 1999; STORET LDC 2001; VDEQ-CBP 1987; VDEQ-WQS 1998, 2001; VDOH-DSS 2000

Notes: * = Reported on a dry weight basis; Location A = near the eastern end of Site 13; Location B = south of the eastern end of Willoughby Spit; Location C = near the center of Willoughby Bay

Abbreviations: mg/kg = milligrams per kilogram; N/A = not applicable; RBC = risk-based concentration.

TABLE 7. Summary of Contaminants Detected in the Vicinity of the Camp Allen Elementary School

Contaminant	Maximum detected concentration	Unit	Location of maximum detection	CV	Type of CV
Soil samples					
Arsenic	25.1*	mg/kg	about 200 feet west of the school	0.5	CREG
Cadmium	31.3	mg/kg	about 75 feet west of the school	10	child c-EMEG
Chromium	869	mg/kg	about 75 feet west of the school	200	child RMEG, Cr VI
Drainage ditch surface water samples					
Antimony	20.6	μg/L	> 1,000 west of the school	4	child RMEG
Arsenic	11.5	μg/L	> 1,000 west of the school	0.02	CREG
Iron	14,300	μg/L	> 1,000 west of the school	11,000	RBC-N
Lead	53.6	μg/L	> 1,000 west of the school	15	EPA Action Level
Manganese	574	μg/L	> 1,000 west of the school	500	child RMEG
Drainage ditch sediment samples					
Arsenic	23 (shallow), 6.4 (deep)	mg/kg	> 1,000 west of the school about 200 feet south of the school	0.5	CREG
Air samples					
Benzene	0.7	$\mu g/m^3$	Two classroom sampling locations, maintenance area	0.1	CREG
Hexachlorobutadiene	0.3	$\mu g/m^3$	One classroom sampling location, gymnasium, maintenance area	0.05	CREG

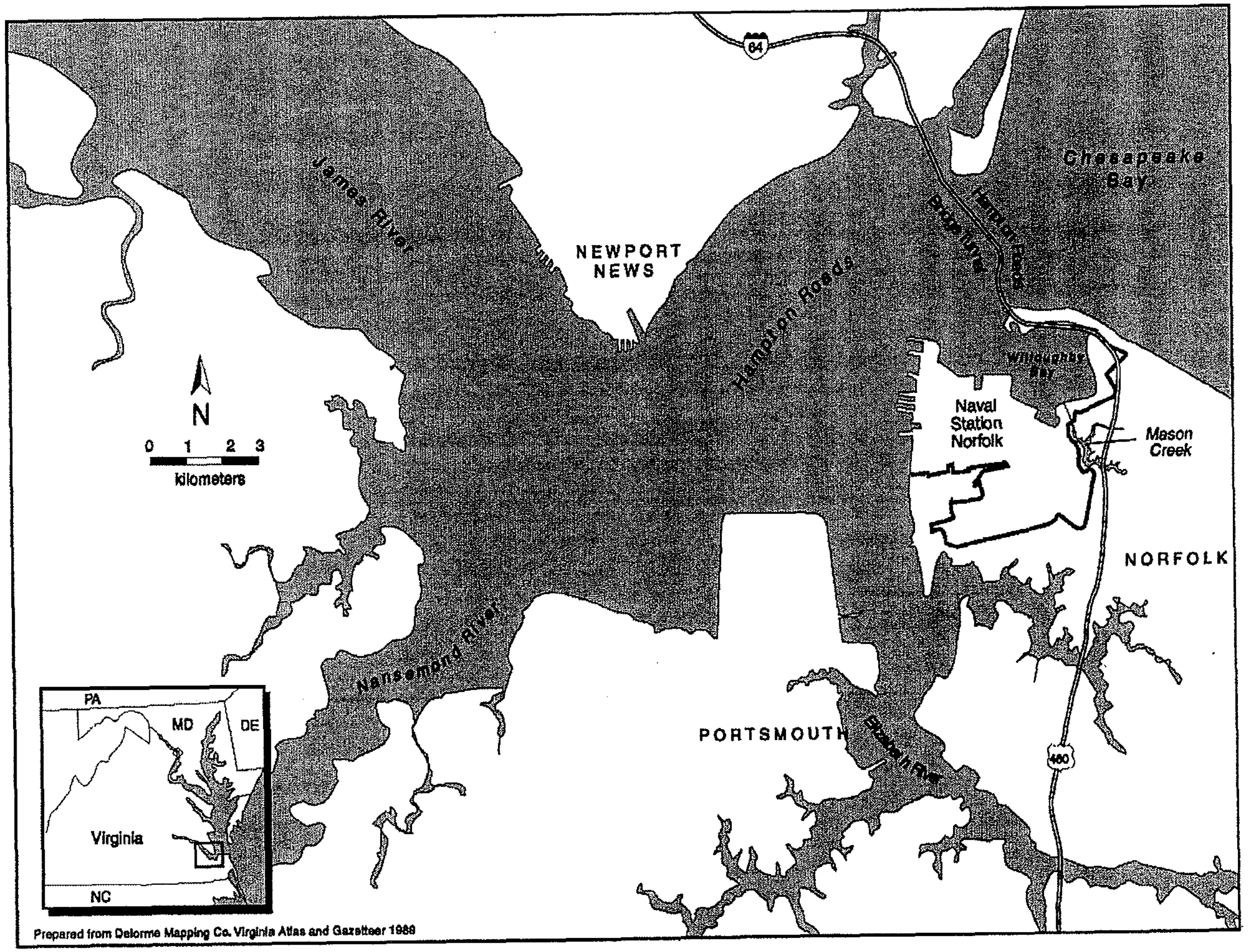
Sources: Baker 1994a, b, c, 1995a, 1997

Notes:
* The laboratory analyses for arsenic returned concentrations of arsenic that were thought to be biased low, indicating that actual arsenic concentrations might have been higher.

Abbreviations:
CREG = cancer risk evaluation guide
CV = comparison value
c-EMEG = environmental media evaluation guide, chronic exposure
mg/kg = milligrams/kilogram
RBC-N = risk-based concentration, noncarcinogenic effects
RMEG = reference dose media evaluation guide
μg/L = micrograms/liter
$\mu g/m^3$ = micrograms/cubic meter

FIGURES

FIGURE 1. Location of Naval Station Norfolk



Source: NOAA 1997

FIGURE 2. Installation Restoration Program Sites at Naval Station Norfolk

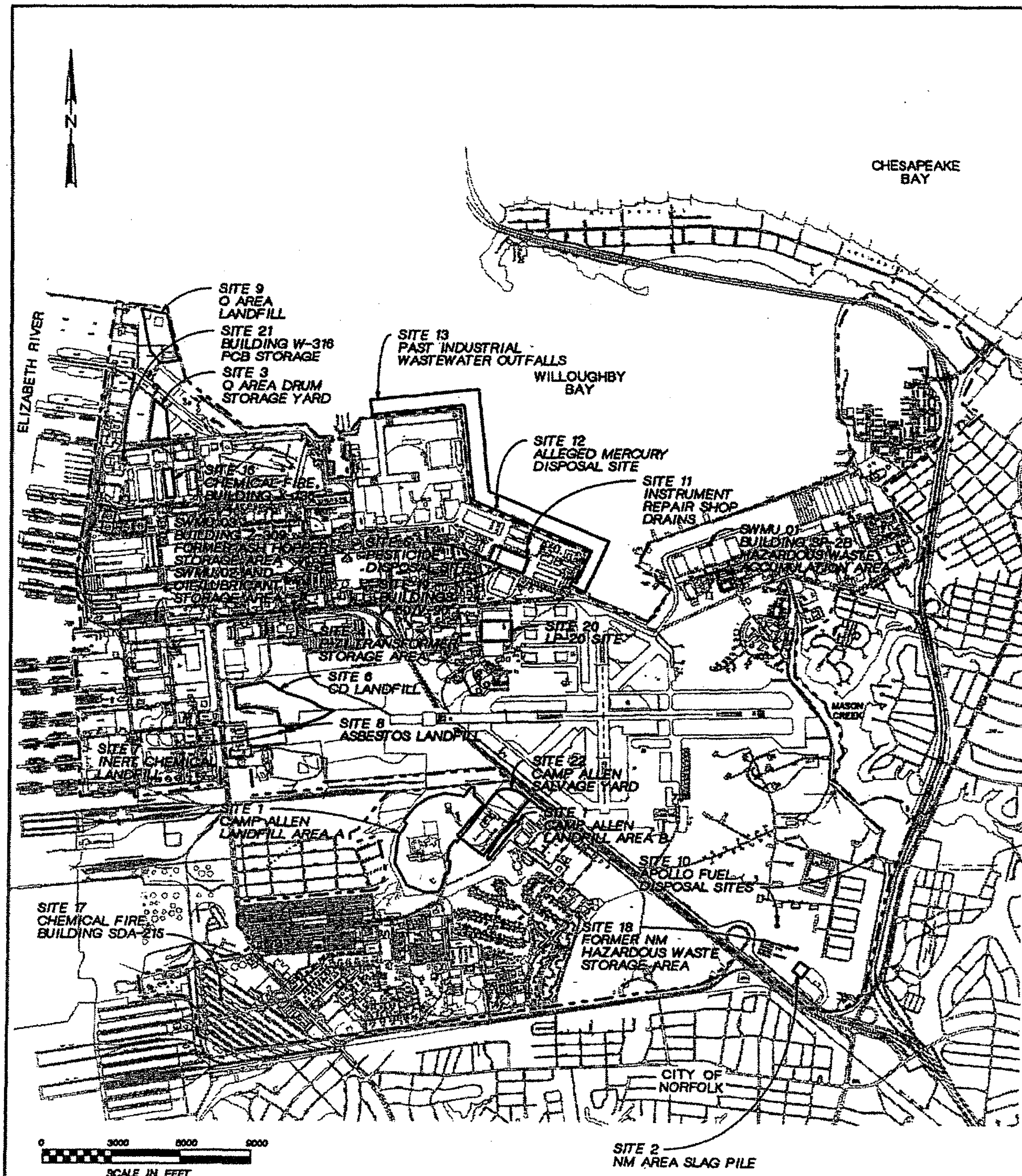
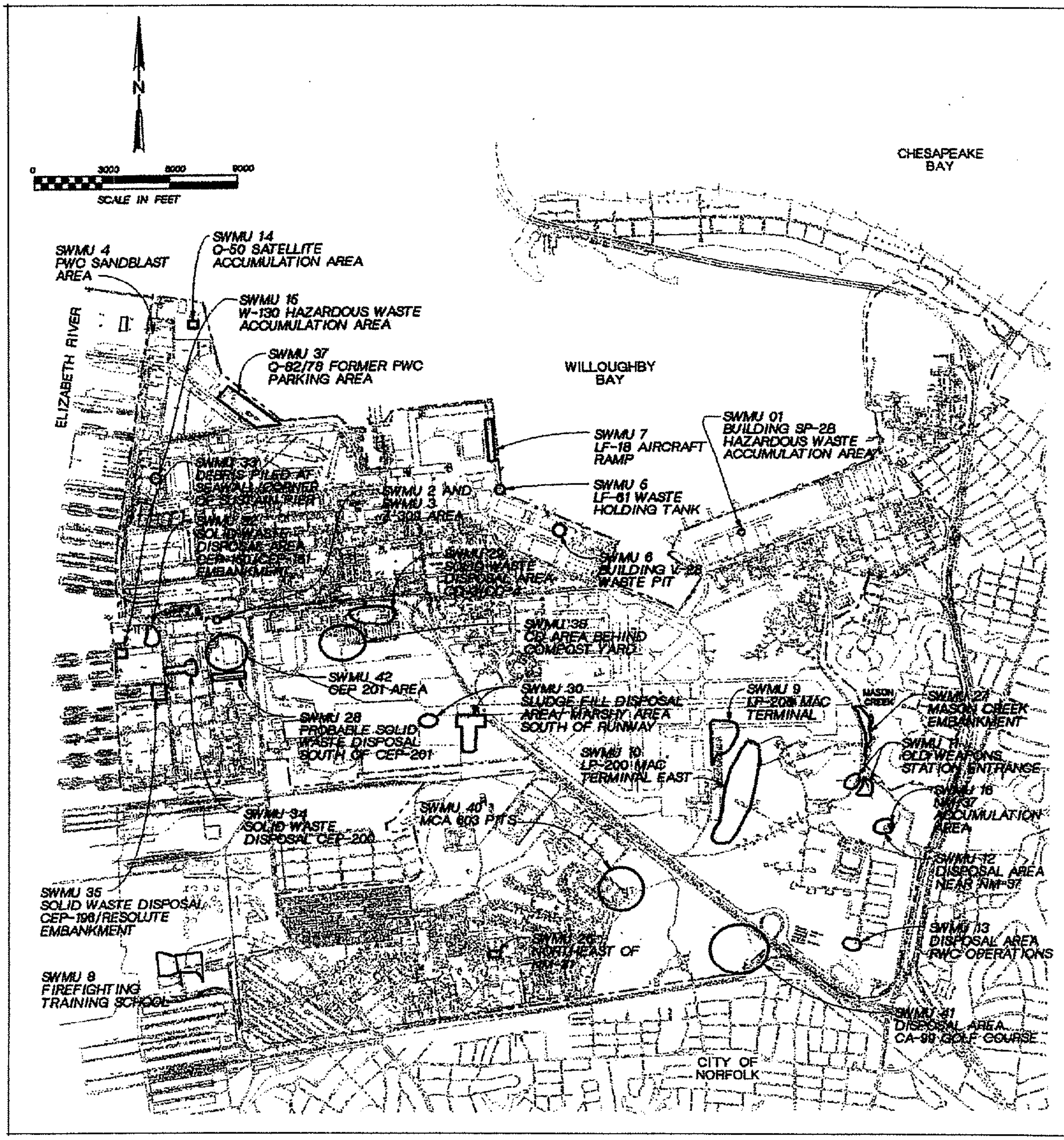


FIGURE 3. Solid Waste Management Units at Naval Station Norfolk



Source: CH2MHILL 1999

Figure 4. ATSDR's Exposure Evaluation Process

REMEMBER: For a public health threat to exist, the following three conditions must all be met:

- Contaminants must exist in the environment
- People must come into contact with areas that have potential contamination
- The amount of contamination must be sufficient to affect people's health

Are the Environmental Media Contaminated?

ATSDR considers:

Soil
Ground water
Surface water and sediment
Air
Food sources

Are People Exposed To Areas With Potentially Contaminated Media?

For exposure to occur, contaminants must be in locations where people can contact them.

People may contact contaminants by any of the following three exposure routes:

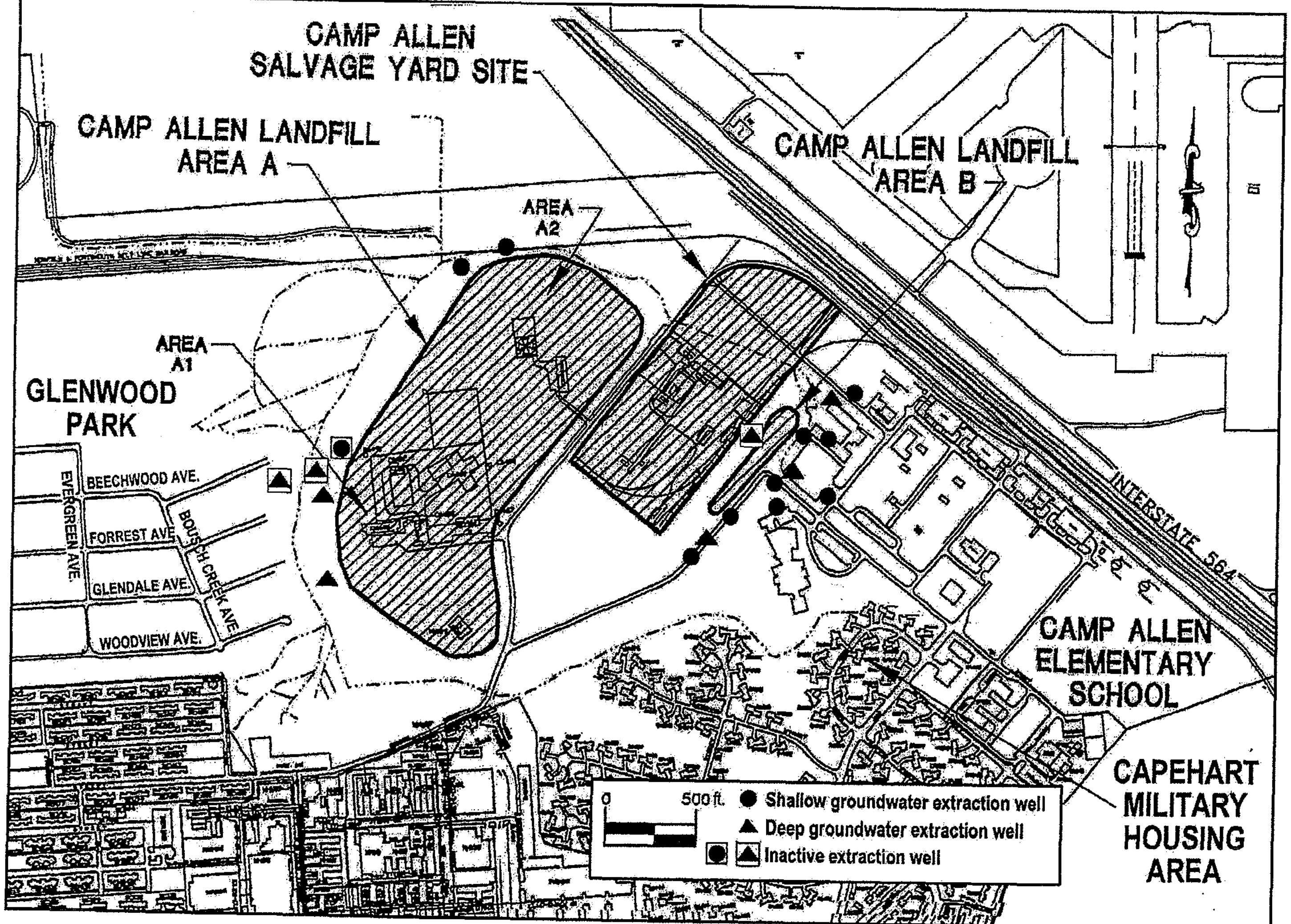
Inhalation
Ingestion
Dermal absorption

For Each Completed Exposure Pathway, Will the Contamination Affect Public Health?

ATSDR will evaluate existing data on contaminant concentration and exposure duration and frequency.

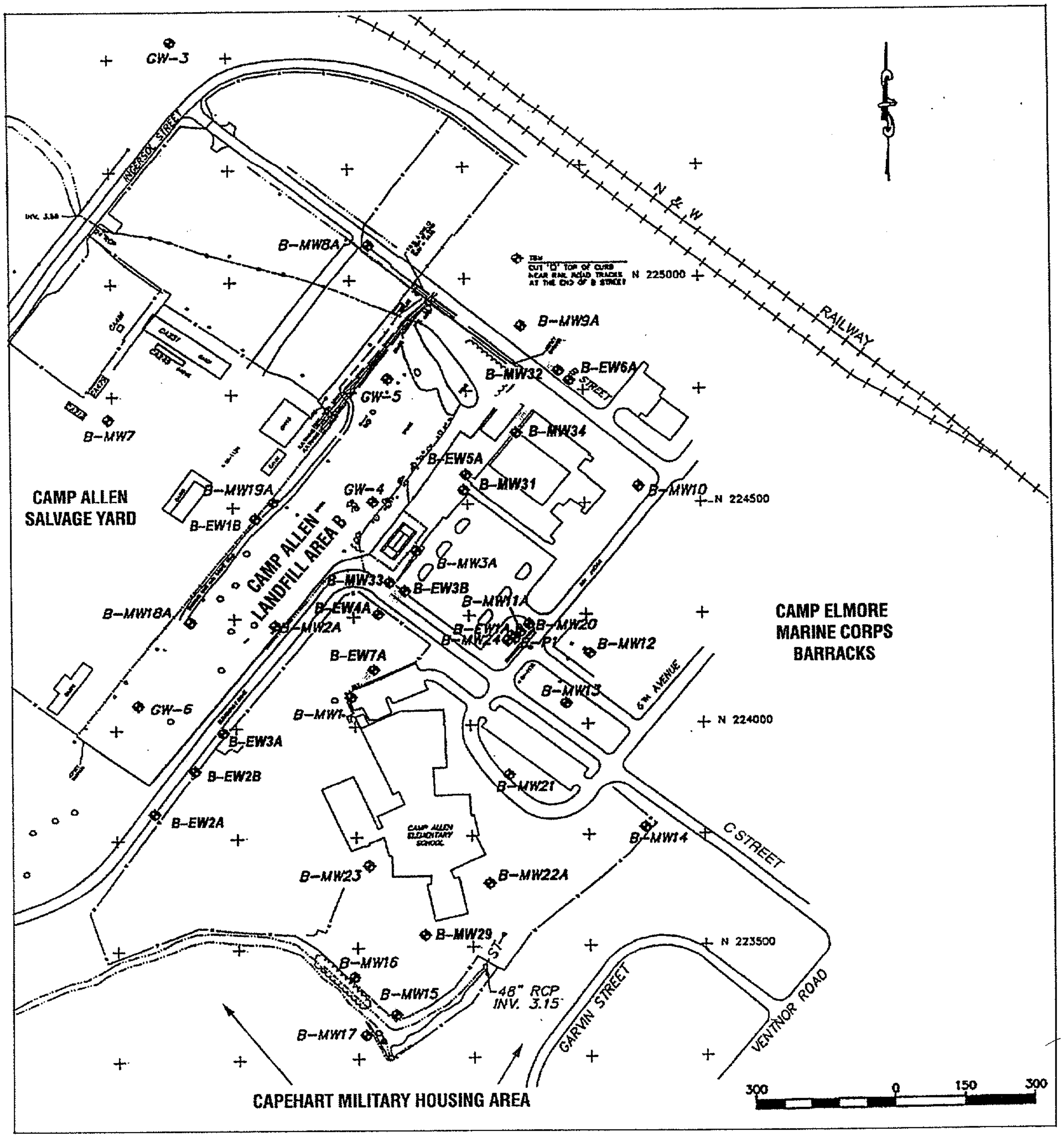
ATSDR will also consider individual characteristics (such as age, gender, and lifestyle) of the exposed population that may influence the public health effects of contamination.

FIGURE 5. Camp Allen Landfill and Vicinity



Source: Baker 1994c

FIGURE 6. Camp Allen Landfill Area B



Sources: Baker 1994c; CH2MHILL 2001b

Abbreviations: EW = extraction well; MW = monitoring well

Notes: Shallow aquifer extraction wells are denoted A (after the well number)
Deep aquifer extraction wells are denoted B (after the well number)

Appendix A: Evaluation of Potential Public Health Hazards at Sites Under Investigation at Naval Station Norfolk

Site	Site Description/ Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities and/or Current Status	Public Health Evaluation
		Installation Restoration Program (IRP) Sites		
Site 1: Camp Allen Landfill (Area A)	Area A, now vegetated, was used for refuse disposal from the mid-1940s until approximately 1974. Materials accepted at the 45-acre landfill included metal plating and parts cleaning sludge, residues from organic solvents and paint stripping, and fly ash from the power plant, as well as general trash and debris. Part of the area is currently occupied by the base brig and a heliport.	**Air:** In 33 1993 samples collected within the brig, the volatile organic compounds (VOCs) detected at levels above comparison values (CVs) were: benzene (1 micrograms/cubic meter [$\mu g/m^3$]), benzyl chloride (0.9 $\mu g/m^3$), 1,1,1-trichloroethane (1,1,1-TCA) (3,400 $\mu g/m^3$), hexachlorobutadiene (1 $\mu g/m^3$), chloroform (0.8 $\mu g/m^3$), methylene chloride (380 $\mu g/m^3$), and 1,2,4-trimethylbenzene (21 $\mu g/m^3$). **Soil:** In 5 1992 surface soil samples, Aroclor-1260 (0.42 milligrams/kilogram [mg/kg]), arsenic (70 mg/kg), cadmium (88.9 mg/kg), and lead (683 mg/kg) exceeded CVs. **Groundwater:** Thirty-two 1992 and 1993 shallow groundwater samples contained vinyl chloride (12,000 micrograms/liter [$\mu g/L$]), methylene chloride (1,500 $\mu g/L$), acetone (2,600 $\mu g/L$), 1,2-dichloroethene (1,2-DCE) (9,500 $\mu g/L$), 1,2-dichloroethane (1,2-DCA) (270 $\mu g/L$), trichloroethylene (TCE) (5,600 $\mu g/L$), tetrachloroethylene (PCE) (620 $\mu g/L$), benzene (430 $\mu g/L$), 4-methyl-2-pentanone (25,000 $\mu g/L$), toluene (18,000 $\mu g/L$), 2-butanone (10,000 $\mu g/L$), bis(2-ethylhexyl)phthalate (B2EHP) (97 $\mu g/L$), phenol (5,100 $\mu g/L$), 2,4-dimethylphenol (1,600 $\mu g/L$), 2-methylphenol (3,500 $\mu g/L$) 4-methylphenol (28,000 $\mu g/L$), aldrin (0.026 $\mu g/L$), heptachlor epoxide (0.005 $\mu g/L$), 4,4'-DDD (0.11 $\mu g/L$), aluminum (132,000 $\mu g/L$), antimony (1,800 $\mu g/L$), arsenic (900 $\mu g/L$), barium (7,270 $\mu g/L$), beryllium (10.6 $\mu g/L$), cadmium (540 $\mu g/L$), chromium (117,000 $\mu g/L$), iron (226,000 $\mu g/L$), lead (58,000 $\mu g/L$), manganese (3,220 $\mu g/L$), nickel (352 $\mu g/L$), thallium (42 $\mu g/L$), vanadium (396 $\mu g/L$), zinc (7,700 $\mu g/L$), and cyanide (380 $\mu g/L$) at levels exceeding CVs. Thirty 1997-2001 samples contained, for the most part, the same contaminants present at lower concentrations. Also present was 1,1-dichloroethene (1,1-DCE) (1 $\mu g/L$), 1,1,2,2-tetrachloroethane (1,1,2,2-TCA) (0.6 $\mu g/L$), and 1,2-dibromoethane (0.3 $\mu g/L$). Seventy 1991-1993 deep groundwater samples contained vinyl chloride (350 $\mu g/L$), methylene chloride (131 $\mu g/L$), 1,1-DCE (8 $\mu g/L$), 1,2-DCE (660 $\mu g/L$), 1,2-DCA (44 $\mu g/L$), TCE (170 $\mu g/L$), benzene (3 $\mu g/L$), chloroform (8 $\mu g/L$), chloromethane (11 $\mu g/L$), bis(2-chloroethyl)ether (2 $\mu g/L$), B2EHP (3.5 $\mu g/L$), heptachlor epoxide (0.0065 $\mu g/L$), aluminum (46,900 $\mu g/L$), antimony (9.6 $\mu g/L$), arsenic (64.4 $\mu g/L$), cadmium (6.5 $\mu g/L$), chromium (166 $\mu g/L$), iron (248,500 $\mu g/L$), lead (44.2 $\mu g/L$), manganese (2,170 $\mu g/L$), thallium (6 $\mu g/L$), and vanadium (356 $\mu g/L$) at levels above CVs. In 54 samples collected from 1997 to 2001, concentrations of VOCs increased in some wells and decreased in others, but did not exceed the previously-detected maxima overall, except 1,2-DCE (791 $\mu g/L$), 1,1,2-trichlorethane (0.9 $\mu g/L$), 1,1,2,2-TCA (3 $\mu g/L$), and benzene (4.9 $\mu g/L$). **Surface Water/Sediment:** In 36 1991-1992 sediment samples, benzo(a)pyrene (0.32 mg/kg), Aroclor-1260 (1.5 mg/kg), arsenic (590 mg/kg), cadmium (183 mg/kg), chromium (3,000 mg/kg), iron (95,400 mg/kg), and lead (1,000 mg/kg) exceeded CVs. In 28 1983-1992 surface water samples, vinyl chloride (8 $\mu g/L$), methylene chloride (14 $\mu g/L$), TCE (18 $\mu g/L$), benzene (1 $\mu g/L$), PCE (20 $\mu g/L$), 1,2-DCE (4 $\mu g/L$), B2EHP (13 $\mu g/L$), alpha-BHC (0.016 $\mu g/L$), dieldrin (0.027 $\mu g/L$), 4,4'-DDD (0.26 $\mu g/L$), Aroclor-1254 (0.44 $\mu g/L$), heptachlor epoxide (0.006 $\mu g/L$), aluminum (20,300 $\mu g/L$), arsenic (500 $\mu g/L$), cadmium (80 $\mu g/L$), chromium (400 $\mu g/L$), iron (78,300 $\mu g/L$), lead (1,300 $\mu g/L$), manganese (697 $\mu g/L$), mercury (3.9 $\mu g/L$), selenium (100 $\mu g/L$), thallium (240 $\mu g/L$), and vanadium (103 $\mu g/L$) exceeded CVs.	After a remedial investigation (RI) and feasibility study (FS) for the landfill were completed in 1994, a Decision Document was issued requiring treatment of soil and groundwater in both aquifers. In July 1997, systems to pump and treat groundwater began operating in Areas A and B. A dual-vapor extraction system to address "hot spots" of contamination in Area A began operating in May 1998. Annual groundwater and surface water monitoring began in 1999.	Air poses no apparent public health hazard because VOCs were present at levels that would not be expected to cause adverse health effects. Soil, surface water, and sediment pose no apparent public health hazard, as any exposures would be brief, infrequent, and incidental, and the detected levels of contaminant would not be expected to result in adverse health effects. There are no known wells drawing from either aquifer that are used for drinking water near the site, so groundwater poses no public health hazard.

Appendix A: Evaluation of Potential Public Health Hazards at Sites Under Investigation at Naval Station Norfolk (continued)

Site	Site Description/ Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities and/or Current Status	Public Health Evaluation
Site 1: Camp Allen Landfill (Area B)	Area B is 2 acres in size and is now vegetated. Waste, including drums holding various chemicals from a fire at the Camp Allen Salvage Yard, was buried in trenches in this area in 1971.	**Air:** In 15 samples collected within the Camp Allen Elementary School in 1992, hexachlorobutadiene (0.3 $\mu g/m^3$) and benzene (0.7 $\mu g/m^3$) exceeded CVs. **Soil:** In 1992, 6 samples contained Aroclor-1260 (0.78 mg/kg), arsenic (13.8 mg/kg), and cadmium (20.5 mg/kg) at concentrations exceeding CVs. Three samples collected from the Camp Allen Elementary School in 1992 and analyzed for metals revealed arsenic (25.1 mg/kg), cadmium (31.3 mg/kg), and chromium (869 mg/kg) at levels exceeding CVs. In 10 1998 samples collected from the landfill after the removal action, benzo(a)pyrene (0.31 mg/kg) and arsenic (42 mg/kg) were detected at levels exceeding CVs. **Groundwater:** From 1983 to 2001, 88 samples from monitoring wells and 55 Geoprobe samples contained acetone (8,300 μg/L), vinyl chloride (3,000 μg/L), methylene chloride (24,000 μg/L), 1,1-DCE (180 μg/L), 1,2-DCE (3,900 μg/L), 1,2-DCA (520 μg/L), TCE (2,100 μg/L), benzene (1,200 μg/L), PCE (48 μg/L), toluene (290 μg/L), 4-methyl-2-pentanone (2,100 μg/L), chloroethane (16 μg/L), chlorobenzene (110 μg/L), trichloroflouromethane (2,300 μg/L), pentachlorophenol (110 μg/L), naphthalene (120 μg/L), bis(2-chloroethyl)ether (8 μg/L), B2EHP (9.6 μg/L), heptachlor epoxide (0.006 μg/L), dieldrin (0.94 μg/L), 4,4'-DDD (0.14 μg/L), aluminum (610,000 μg/L), antimony (48.4 μg/L), arsenic (360 μg/L), barium (1,900 μg/L), beryllium (18.5 μg/L), cadmium (80 μg/L), chromium (1,700 μg/L), iron (734,500 μg/L), lead (1,880 μg/L), manganese (4,880 μg/L), nickel (433 μg/L), thallium (270 μg/L), vanadium (1,610 μg/L), and cyanide (920 μg/L) at concentrations exceeding CVs. Forty-one 1991-2001 deep groundwater samples contained levels of vinyl chloride (4.8 μg/L), methylene chloride (7 μg/L), 1,1-DCE (5 μg/L), 1,2-DCA (1,500 μg/L), 1,2-DCE (83 μg/L), TCE (450 μg/L), benzene (170 μg/L), gamma-BHC (0.15 μg/L), heptachlor epoxide (0.0105 μg/L), dieldrin (0.009 μg/L), aluminum (146,000 μg/L), antimony (25.2 μg/L), arsenic (194 μg/L), beryllium (11.2 μg/L), cadmium (30.8 μg/L), chromium (542 μg/L), iron (428,000 μg/L), lead (183 μg/L), manganese (4,740 μg/L), nickel (203 μg/L), and vanadium (769 μg/L) above CVs. **Surface Water/Sediment:** Thirteen 1983-1992 surface water samples contained vinyl chloride (42 μg/L), methylene chloride (12 μg/L), chloroform (24 μg/L), 1,1-DCE (3 μg/L), 1,2-DCA (32 μg/L), 1,2-DCE (78 μg/L), bromodichloromethane (6 μg/L), TCE (130 μg/L), benzene (25 μg/L), PCE (6 μg/L), B2EHP (13 μg/L), aluminum (31,600 μg/L), antimony (20.6 μg/L), arsenic (340 μg/L), cadmium (180 μg/L), chromium (180 μg/L), iron (58,700 μg/L), lead (2,100 μg/L), manganese (574 μg/L), vanadium (135 μg/L), and zinc (4,700 μg/L) at levels above CVs. Sediment samples collected in 1991 and 1992 contained pentachlorophenol (110 mg/kg), benzo(a)pyrene (0.23 mg/kg), dieldrin (0.086 mg/kg), 4,4'-DDD (4.2 mg/kg), 4,4'-DDT (2.495 mg/kg), and Aroclor-1254 (7.6 mg/kg), arsenic (52.5 mg/kg), cadmium (71.7 mg/kg), chromium (225 mg/kg), copper (22,700 mg/kg), iron (125,000 mg/kg), lead (1,750 mg/kg), nickel (1,255 mg/kg), and vanadium (542 mg/kg) at levels exceeding CVs. Three sediment samples collected in 1998, after the removal action, contained benzo(a)pyrene (0.26 mg/kg), Aroclor-1260 (1.3 mg/kg), antimony (22.2 mg/kg), arsenic (98.9 mg/kg), cadmium (46.9 mg/kg), iron (53,200 mg/kg), and lead (1,180 mg/kg) at levels above CVs.	From May 1994 through January 1995, a removal action designed to address the primary source areas of contamination, including soil, debris, and buried drums, was conducted at Area B. For additional activities and status information, see Area A.	Air, surface water, sediment, deep groundwater, and soil pose no apparent public health hazard. Under expected exposure scenarios, the detected levels of contaminants would not be expected to cause adverse health effects. There are no known drinking water wells located downgradient.

Appendix A: Evaluation of Potential Public Health Hazards at Sites Under Investigation at Naval Station Norfolk (continued)

Site	Site Description/ Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities and/or Current Status	Public Health Evaluation
Site 2: Naval Magazine (NM) Slag Pile	This approximately 2-acre site was used in the 1950s and 1960s for the disposal of slag from aluminum smelting operations. Ash was apparently used to level the area. The site was later regraded and vegetated, and part of it was made into a gravel parking lot. An adjacent drainage channel drains to other culverts and then to Mason Creek. Virginia Department of Environmental Quality (VDEQ) records indicate that a well was drilled in 1949 at a roller rink more than 2,000 feet southeast of the site.	**Soil:** Five surface soil samples from 1996 and 1997 contained arsenic (18.7 mg/kg) and benzo(a)pyrene (0.13 mg/kg) at concentrations exceeding CVs. **Groundwater:** Aluminum (346,000μg/L), antimony (11.8 μg/L), arsenic (225 μg/L), barium (974 μg/L), cadmium (2.9 μg/L), chromium (675 μg/L), iron (248,000 μg/L), lead (357 μg/L), manganese (861 μg/L), thallium (9.9 μg/L), and vanadium (1,070 μg/L) were detected in 32 groundwater samples from 1996 and 1997 at concentrations exceeding CVs. **Surface Water/Sediment:** In 1996 and 1997, 21 surface water samples collected from locations within 400 feet of the site contained aluminum (47,400 μg/L), antimony (22.5 μg/L), arsenic (22.1 μg/L), cadmium (38.6 μg/L), chromium (134 μg/L), copper (2,120 μg/L), iron (49,500 μg/L), lead (1,190 μg/L), manganese (698 μg/L), nickel (106 μg/L), thallium (9 μg/L), vanadium (95 μg/L), and acetone (35,602 μg/L) at concentrations exceeding CVs. In 26 sediment samples collected concurrently, antimony (63.7 mg/kg), arsenic (25.3 mg/kg), cadmium (48.1 mg/kg), chromium (292 mg/kg), copper (5,510 mg/kg), iron (65,500 mg/kg), and lead (3,900 mg/kg) were detected at concentrations exceeding CVs.	An RI and FS for the site were completed in 1998. In summer 1999, contaminated sediment was removed from the adjacent drainage channel, parts of the area were paved, and 1 foot of clean fill was placed on top of other parts. Monitoring is ongoing, and a final Record of Decision (ROD) requiring institutional controls was signed in 2001.	Soil, surface water, and sediment pose no apparent public health hazard because the levels of contaminants detected in these media are too low to cause adverse health effects to individuals with short, incidental, and infrequent exposures. Groundwater poses no public health hazard because it is not expected to impact any wells. Groundwater flows to the east northeast. It is not known for what purposes and for how long the well at the roller rink southeast of the site was used, but this well is not expected to be in the path of any groundwater contamination migrating from the site.

Appendix A: Evaluation of Potential Public Health Hazards at Sites Under Investigation at Naval Station Norfolk (continued)

Site	Site Description/ Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities and/or Current Status	Public Health Evaluation
Site 3: Q Area Drum Storage Yard	Ten of thousands of drums were stored in this 5-acre area while it was in use, from the 1950s until the late 1980s. The drums, which sometimes spilled, held such chemicals as petroleum products, chlorinated organic solvents, paint thinners, and pesticides. The drums were removed, and part of the site was paved and used as a parking lot. The site is located within 1,200 feet of the Elizabeth River (to the west) and Willoughby Bay (to the northeast). It is currently fenced.	**Soil:** Four 1982 composite samples and 8 1986 surface soil samples contained n-nitrosodi-n-propylamine (10 mg/kg), arsenic (38 mg/kg), and thallium (22 mg/kg) at concentrations exceeding CVs. Elevated levels of total pesticides were also detected. After a soil removal action, during the RI, soil samples were collected at a depth of 0" - 18". No VOCs (measured in 24 samples) or semi-volatile organic compounds (SVOCs) (measured in 10 samples) were found at levels above CVs. **Groundwater:** The Yorktown and Columbia Aquifers are hydraulically connected at the site. RI samples collected between 1990 and 1993 and baseline samples from 1998 contained levels of acetone (1,300 μg/L), 1,1-DCE (140 μg/L), cis-1,2-DCE (230 μg/L), trans-1,2-DCE (710 μg/L), 1,2-DCA (410 μg/L), 1,1,1-TCA (1,100 μg/L), TCE (1,371 μg/L), PCE (8,200 μg/L), vinyl chloride (34 μg/L), methylene chloride (780 μg/L), chloroform (60 μg/L), carbon tetrachloride (120 μg/L), bromodichloromethane (120 μg/L), antimony (97 μg/L), arsenic (337 μg/L), beryllium (33 μg/L), cadmium (96 μg/L), chromium (1,120 μg/L), lead (516 μg/L), nickel (472 μg/L), and selenium (90 μg/L) above CVs. Results from 12 samples analyzed between 1983 and 1986 (before the contaminated soil removal) were similar; however, antimony (2,300 μg/L), arsenic (500 μg/L), chromium (140,000 μg/L), thallium (150 μg/L), trans-1,2-DCE (9,000 μg/L), TCE (6,000 μg/L), and B2EHP (130 μg/L) were detected at higher concentrations in the 1980s than the 1990s. During five rounds of sampling conducted since the groundwater treatment system began operating, levels of 1,1-DCE (25 μg/L), 1,2-DCA (100 μg/L), cis-1,2-DCE (320 μg/L), PCE (35 μg/L), TCE (470 μg/L), and vinyl chloride (110 μg/L) exceeded CVs. **Sediment:** Two sediment samples collected from the storm drain conduits at the site in 1993 were analyzed for VOCs, metals, pesticides, and polychlorinated biphenyls (PCBs). Arsenic (5.84 mg/kg), iron (26,400 mg/kg), gamma-chlordane (17,600 mg/kg), and alpha-chlordane (15,900 mg/kg) were present at concentrations exceeding CVs.	In 1987, the Navy excavated 750 cubic yards of soil from the site and paved the affected area. An RI/FS addressing the site was completed in 1996. In August 1998, an air sparging/soil vapor extraction system (AS/SVE) was installed at the perimeter of the groundwater contamination plume and in the most contaminated area within the plume (the "hot spot") to address subsurface VOCs. Long-term monitoring of groundwater and soil gas is underway. Part of the site will be considered for closeout in 2002.	Soil poses no apparent public health hazard. Contaminated soil has been removed and access to the area is now controlled. Prior exposures were probably uncommon and of short duration. Under such circumstances, detected contaminant levels in surface soil were too low to cause adverse health effects. Because there are no drinking water intakes near the site, groundwater poses no public health hazard. Sediment also poses no apparent public health hazard because any public exposure to storm drain sediment would be accidental, brief, and unusual, and levels of contaminants detected would not cause adverse health effects under such circumstances.

Appendix A: Evaluation of Potential Public Health Hazards at Sites Under Investigation at Naval Station Norfolk (continued)

Site	Site Description/ Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities and/or Current Status	Public Health Evaluation
Site 4: P-71 Transformer Storage	New and out-of-service transformers were stored in this area from the 1940s until 1978.	**Soil:** Samples from 42 soil borings were collected in 1983 and 1984 and analyzed for PCBs. Most samples contained Arcolor-1260, and the highest detected concentration in surface soil was 890 mg/kg, which exceeds the CV. In 1991, 37 soil samples (28 of them from surface soil) analyzed for PCBs all contained Aroclor-1260. The maximum detected concentration, 500 mg/kg, exceeds the CV. **Groundwater:** Three monitoring wells were sampled for PCBs in March and June 1991. Samples from two of the wells contained Aroclor-1260 at concentrations (reaching 11.0 μg/L) that exceeded CVs. Two June 1991 samples collected from off-site monitoring wells did not contain detectable levels of PCBs. Samples collected after remediation, in 1995, from the three on-site wells contained concentrations of PCBs below the detection limits of 1.0 and 2.0 μg/L.	An RI/FS for this site was completed in 1991. The remediation of PCB-contaminated soil and groundwater was completed in 1992. Follow-up groundwater monitoring was conducted in 1995. No further action is planned at this site.	Any public exposures to soil at this site would be limited and infrequent, and the PCB levels detected are too low to cause adverse health effects in such circumstances. Thus, soil poses no public health hazard. Groundwater does not pose a public health hazard because the only wells near the site are directly to the west (not the expected direction of groundwater flow), and they are not used for drinking water.
Site 5: Pesticide Disposal Site	At this site, there was a culvert about 2 feet in diameter placed vertically into a hole filled with gravel, known as a "french drain." It was used for the disposal of pesticide application rinse water and over-age concentrated pesticides from a nearby pest control shop that operated from the late 1960s through 1973. The area is currently fenced and used for storage. Two nearby storm drains carry surface runoff to Willoughby Bay.	**Soil:** In 1988, soil samples were analyzed for SVOCs, pesticides, and PCBs. Chlordane (6.3 mg/kg) and dieldrin (8.3 mg/kg) exceeded CVs. In 1995, five samples were collected and analyzed for VOCs, SVOCs, pesticides, PCBs, and metals. Arsenic (12.5 mg/kg) was detected at concentrations exceeding CVs. In 1997, six samples were analyzed for pesticides, and detected levels of dieldrin (0.43 mg/kg) exceeded CVs. **Groundwater:** In 1995 samples from three wells, thallium (9 μg/L) exceeded CVs. The wells were inadvertently installed upgradient of the site, and pesticides were not detected in the samples. In 1997, the three existing wells and two new wells were sampled for pesticides. Samples from one well contained levels of 4,4'-DDD (16 μg/L) exceeding the CV.	A Site Investigation (SI) was completed in early 1998. In late 1999, pesticide-contaminated soil was removed. A Closeout Report for the site has been drafted.	Soil poses no apparent public health hazard. The site is fenced and contaminated soil has been removed. Any past exposures were probably uncommon and of short duration. Under these circumstances, detected contaminant levels in surface soil would not cause adverse health effects. Groundwater poses no public health hazard because there is no exposure (i.e., there are no wells near the site).

Appendix A: Evaluation of Potential Public Health Hazards at Sites Under Investigation at Naval Station Norfolk (continued)

Site	Site Description/ Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities and/or Current Status	Public Health Evaluation
Site 6: CD Landfill	Beginning in 1979, the western section of the site was permitted to accept demolition debris and inert debris other than ash, chemicals, or asbestos. For 2 years, it accepted grit used for sandblasting cadmium-plated aircraft parts. The western section closed in 1987. The eastern section of the site, although unpermitted, received such waste as demolition debris, chemicals, asbestos, sandblasting grit, and power plant ash from 1974 to 1979. The southeast corner of this section was regraded in 1979 to allow runway expansion, and excess material was spread over the remainder of the landfill. The entire site covers approximately 22 acres. In 1993, a road was constructed over the site, and some regrading occurred. A fence was installed on either side of the road to prevent public access to the landfill.	**Soil:** 1991 surface soil samples contained dieldrin (0.051 mg/kg), arsenic (34.9 mg/kg), and lead (1,040 mg/kg) at levels exceeding CVs. Two composite samples analyzed for radium-226 (reaching 0.58 picoCuries/gram [pCi/g]) and 5 composite and surface soil samples analyzed for thorium-230 (reaching 0.98 pCi/g) contained levels of these radionuclides that exceeded screening values. However, they are thought to be naturally-occurring, and there has been no documented disposal of radioactive materials at the site. **Groundwater:** In 1993, 25 samples from the shallow aquifer contained the following contaminants at concentrations exceeding CVs: chlorobenzene (2,000 μg/L), B2EHP (9 μg/L), beta-BHC (0.034 μg/L), heptachlor epoxide (0.032 μg/L), dieldrin (0.04 μg/L), Aroclor-1260 (0.12 μg/L), aluminum (208,000 μg/L), antimony (33.6 μg/L), arsenic (65.6 μg/L), cadmium (21.8 μg/L), chromium VI (309 μg/L), iron (177,000 μg/L), lead (864 μg/L), manganese (6,560 μg/L), nickel (138 μg/L), thallium (1.1 μg/L), vanadium (504 μg/L), and zinc (3,780 μg/L). Levels of cadmium, iron, and lead measured in 12 1991 samples were lower. Two samples from a well drawing from the deep aquifer were analyzed in 1993; arsenic (2.8 μg/L) and lead (16.9 μg/L) were detected at levels exceeding CVs. After the landfill was capped in 1999, parameters for which samples were analyzed were limited to a few metals and two VOCs (in the sample from one deep well). These VOCs, 1,4-dichlorobenzene and chlorobenzene, were not detected during 2000 or 2001 sampling. Four rounds of samples from the shallow aquifer collected in 2000 and one round collected in 2001 were analyzed for lead and iron. Lead levels (reaching 110 μg/L) exceeded CVs, but decreased over time. In 2001, only one sample contained lead at a level (65 μg/L) exceeding its CV. Iron levels (reaching 117,000 μg/L during the first round and 35,800 μg/L during subsequent rounds) also exceeded CVs. 1993 analysis of 9 shallow groundwater samples for selected radioisotopes revealed levels of radium-226 (2.61 picoCuries/liter [pCi/L]), radium-228 (3.48 pCi/L), and radon-222 (672 pCi/L) exceeding screening values, but thought to be naturally-occurring. **Surface Water/Sediment:** In 1993, 7 surface water samples from drainage ditches contained dieldrin (0.035 μg/L), aluminum (176,000 μg/L), antimony (22.5 μg/L), arsenic (40.1 μg/L), barium (1,420 μg/L), chromium (299 μg/L), iron (1,470,000 μg/L), lead (712 μg/L), manganese (6,760 μg/L), nickel (253 μg/L), thallium (5 μg/L), and vanadium (1,180 μg/L) at levels above CVs. Surface water samples collected in 2000 and 2001 during post-closure monitoring did not contain chlorobenzene or 1,4-dichlorobenzene. Twelve 1993 shallow sediment samples from drainage ditches contained levels of benzo(a)anthracene (52 mg/kg), benzo(b)flouranthene (54 mg/kg), benzo(k)flouranthene (22 mg/kg), benzo(a)pyrene (38 mg/kg), indeno(1,2,3-cd)pyrene (14 mg/kg), dibenz(a,h)anthracene (3.9 mg/kg), dieldrin (0.12 mg/kg), arsenic (49.2 mg/kg), iron (207,000 mg/kg), and lead (1,260 mg/kg) exceeding CVs. Arsenic (9.2 mg/kg) exceeded its CV in 7 deep sediment samples. Sediment and surface water samples collected from	An RI and FS were completed in 1996, at which time the landfill was divided into two Operable Units (OUs) so that sediment (OU 1) could be addressed separately from soil and groundwater (OU 2). Contaminated sediments were partially removed in 1997. A ROD for OU 2 signed in 1998 requires landfill closure, institutional controls, and post-closure monitoring. In accordance with applicable landfill closure requirements, a cap covering the entire site (including remaining contaminated sediments) was installed in 1999. Long-term monitoring of groundwater and surface water is underway.	Soil, sediment, and surface water pose no apparent public health hazard because there is little, if any, exposure, and the detected levels of contaminants are too low to cause adverse health effects under expected exposure scenarios. A fence has been erected to prevent access from the road. Groundwater does not pose a public health hazard because no potable water wells are potentially affected by site-related contamination. Shallow groundwater flows generally to the northeast, and there are no downgradient wells. Deep groundwater is thought to flow to the north or northwest, and the only identified wells are southwest of the site and used only for industrial purposes.

Appendix A: Evaluation of Potential Public Health Hazards at Sites Under Investigation at Naval Station Norfolk (continued)

Site	Site Description/ Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities and/or Current Status	Public Health Evaluation
Site 7: Inert Chemical Landfill	With the approval of the Virginia Department of Health's (VDOH) Solid and Hazardous Waste Management Division, this landfill was constructed in June 1979 for a one-time disposal of 84 pallets of inert chemicals (mainly unused ion exchange resin). The landfill has a 1-foot clay base, was covered with 2 feet of soil and 1 foot of clay, and has 6-foot clay side berms. A records review also indicated that the site may have received 1,000 5-gallon cans of roofing tar.	**Soil:** Two 1995 samples analyzed for VOCs, SVOCs, and metals contained benzo(a)pyrene (0.52 mg/kg), benzo(b)flouranthene (1.4 mg/kg), arsenic (8.6 mg/kg), and iron (24,900 mg/kg) at levels exceeding CVs. **Groundwater:** No contaminants were found at concentrations exceeding CVs in a 1995 sample analyzed for the same parameters as the soil samples.	The Navy excavated and removed the contents of the disposal area in 1982. On the basis of a 2001 Closeout Report, no further action will be taken at the site.	Public exposures to soil at this site would not be expected, and sporadic exposure to soil contamination at this site would not be expected to result in adverse health effects. Thus, soil poses no apparent public health hazard. Groundwater does not pose a public health hazard because no contaminants were detected.
Site 8: Asbestos Landfill	With VDOH approval, an estimated 6,500 bags of asbestos (double bagged) were disposed of at this site during a single period in June 1979. Like Site 7, the landfill has a clay liner, clay side berms, and was covered. Currently, the site is being used as a gravel parking area primarily for military personnel, secured with limited access.	**Soil:** One sample collected in 1995 and analyzed for VOCs, SVOCs, and metals contained arsenic (11.8 mg/kg), benzo(a)pyrene (0.41 mg/kg), and benzo(b)flouranthene (1.3 mg/kg) at levels exceeding CVs. Asbestos was also detected. **Groundwater:** In 1995, one sample tested for asbestos did not contain detectable levels.	A 2001 Closeout Report recommends that no further remedial activities be taken at the site. The Navy is planning to pave the existing parking lot on top of the site.	Any public exposure to this site would be infrequent, incidental, and of short duration. The contaminants detected in soil would not be expected to cause adverse health effects in these circumstances. Thus, soil poses no apparent public health hazard. Although groundwater at this site has not been sampled for contaminants other than asbestos, there are no wells downgradient of the site, so groundwater does not pose a public health hazard.

Appendix A: Evaluation of Potential Public Health Hazards at Sites Under Investigation at Naval Station Norfolk (continued)

Site	Site Description/ Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities and/or Current Status	Public Health Evaluation
Site 9: Q Area Landfill	This site was developed during a past fill operation and used from 1974 until 1978. Reportedly, only construction debris was left at the landfill. Burning was also conducted at the site. The site is in the northwest corner of the base, adjacent to the water.	**Soil:** Three 1995 samples from the landfill analyzed for VOCs, SVOCs, and metals contained benzo(a)anthracene (4.6 mg/kg), benzo(a)pyrene (3.0 mg/kg), benzo(b)flouranthene (5.6 mg/kg), dibenz(a,h)anthracene (0.18 mg/kg), antimony (52.8 mg/kg), arsenic (17.2 mg/kg), cadmium (11.2 mg/kg), copper (4,790 mg/kg), iron (137,000 mg/kg), and lead (1,500 mg/kg) at concentrations above CVs. **Groundwater:** Benzene (4.9 μg/L), iron (14,700 μg/L), and lead (145 μg/L) were present at concentrations exceeding CVs in 2 1995 samples analyzed for VOCs, SVOCs, and metals. **Surface Water/Sediment:** In 1996, 3 surface water and 2 sediment samples from a lagoon just south of the site were analyzed for VOCs, SVOCs, and metals. Only cadmium (7.6 μg/L), iron (14,700 μg/L), and lead (145 μg/L) were present at concentrations exceeding CVs in the surface water samples. In the sediment samples, arsenic (8.6 mg/kg), benzo(a)pyrene (1.2 mg/kg), benzo(b)flouranthene (2.1 mg/kg) exceeded CVs.	An RI for the site is underway.	Because significant exposure is not expected to contaminants found in soil, surface water, and sediment, these media pose no apparent public health hazard. Because there are no wells near the site, groundwater poses no public health hazard.
Site 10: Apollo Fuel Disposal Sites	From 1967 to 1969, monomethylhydrazine (a fuel component) from several Apollo spacecraft capsules was poured from 55-gallon drums onto the ground in two areas and allowed to percolate into the soil. The areas were fenced during disposal activities.	**Soil:** Only arsenic (2.5 mg/kg) was present at concentrations above CVs in 2 1995 surface soil samples analyzed for VOCs, SVOCs, and metals.	The site was investigated in 2001, but the results of the investigation are not yet available.	Detected concentrations of arsenic may be naturally-occurring and are too low to result in adverse health effects under expected exposure scenarios. Thus, soil does not pose a public health hazard. Groundwater has not been sampled, but is not expected to pose a public health hazard because the only nearby off-site well is more than 0.5 miles southeast of the fuel disposal sites and would not be expected to be affected by any site-related groundwater contamination.

Appendix A: Evaluation of Potential Public Health Hazards at Sites Under Investigation at Naval Station Norfolk (continued)

Site	Site Description/ Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities and/or Current Status	Public Health Evaluation
Site 11: Instrument Repair Shop Drain	From the late 1940s until 1956, paint from ships' dials (containing low levels of radium) was flushed through drains in the instrument repair shop located in Building V-60, contaminating the plumbing.	**Air:** In 1988, a radiological survey of the pluming and storm sewer systems was performed. The level of radon detected in a manhole (10.8 pCi/L) exceeded regulatory values, but was consistent with levels commonly found in underground samples. Sampling also revealed elevated total beta-gamma levels (2,717 disintegrations per minute/100 square centimeters) and gamma exposure rates (22 microroentgens/hour).	In summer 1982, low-level radiological contamination in the plumbing was remediated, and an effort to decontaminate the sanitary sewer and associated areas was undertaken in late 1983. However, Building V-60 caught fire in 1986 (see Site 19) and remediation of the full extent of contamination in the plumbing and storm sewer systems was completed in 1991 as part of the remediation of Site 19.	Air poses no public health hazard because there is no public exposure to air contaminants at this site. The plumbing and storm sewer systems were fully decontaminated and are no longer potential sources of contamination. Any exposures to water after it was carried through the storm sewer system to a discharge point would be limited and not expected to result in adverse health effects; thus, they pose no apparent public health hazard.
Site 12: Mercury Disposal Site	It was reported that, in the late 1960s, approximately 150 10-pound glass bottles of elemental mercury were dumped off the sea wall near Building V-88 into Willoughby Bay, allegedly from a laboratory within the building. However, in 1976, sediment sampling did not reveal mercury contamination and divers could not find any glass containers in the sediment.	**Sediment:** In 1995 and 1996, arsenic (6.9 mg/kg) and benzo(a)pyrene (0.3 mg/kg) were present at levels exceeding CVs in four samples analyzed for VOCs, SVOCs, and metals.	On the basis of the conclusions of a 2001 Closeout Report, no further action is planned at the site.	Sediment sampling suggests that little, if any, contamination is present at this site. Because any exposures would be limited, the site poses no apparent public health hazard.

Appendix A: Evaluation of Potential Public Health Hazards at Sites Under Investigation at Naval Station Norfolk (continued)

Site	Site Description/ Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities and/or Current Status	Public Health Evaluation
Site 13: Past Industrial Wastewater Outfalls	From the 1940s to 1976, the Naval Air Rework Facility Norfolk generated significant quantities of industrial wastewater from metal plating solutions and rinsewaters, paint stripping solutions, and degreasing compounds. The wastewater, contaminated primarily with chromium, cadmium, zinc, cyanide, and phenols, was discharged to the storm sewer system, which discharged to Willoughby Bay.	**Sediment:** Between 1976 and 1978, VDEQ collected three sediment samples near the eastern edge of the site. They were analyzed for 6 metals, and arsenic (6.7 mg/kg), cadmium (12.69 mg/kg), and chromium (207 mg/kg) were present at concentrations exceeding CVs. In 1986, two locations were sampled for metals and polycyclic aromatic hydrocarbons (PAHs), and 1987 samples from three locations were analyzed for PAHs, PCBs, and selected pesticides. In the VDEQ 1986 and 1987 samples, arsenic (26 mg/kg), benzo(a)pyrene (6.99 ppm), and benzo(a)anthracene (6.81 mg/kg), indeno(1,2,3-cd)pyrene (4.24 mk/kg), PCBs (2.69 mg/kg) were detected at concentrations exceeding CVs.	In the mid-1970s, most of the base industrial waste streams were rerouted to the Naval Station Norfolk Industrial Wastewater Treatment Plant, then discharged to the Hampton Roads Sanitation District sewage treatment plant. The remaining discharges from the storm sewer system have been permitted under the National Pollutant Discharge Elimination System (NPDES). Since the former wastewater outfalls have been continually monitored under Naval Station Norfolk's NPDES permit for more than 15 years, no further action is planned for this site.	The outfalls are not expected to have released contaminants at levels of potential health concern since they were permitted. Direct exposures to the water discharged from the outfalls or the sediment immediately adjacent to them are expected to have been incidental, infrequent, and of short duration, to the extent they occurred at all. The contaminants detected in sediments would not cause adverse health effects under such circumstances. No surface water data were provided to ATSDR for review. Exposures to contaminated surface water would have been limited, and ATSDR expects that very little, if any, exposure would have occurred immediately adjacent to the outfall. Thus, adverse health effects would not be expected. Therefore, surface water and sediment pose no apparent public health hazard.
Site 14: Underground Oil Spill—Piers 4, 5, and 7	In 1979, an estimated 100 gallons of diesel oil per day from the fuel distribution system seeped into the ground behind the sea wall near piers 4, 5, and 7. Some of the seepage, attributed to leaks, reached the Elizabeth River. Other releases of petroleum products from fuel distribution facilities in this area have also occurred over the years.	**Groundwater:** In 1991, free product up to 4 feet deep was detected in groundwater samples adjacent to a ruptured pipeline. The approximately 30 samples also contained concentrations of benzene (52 μg/L), naphthalene (500 μg/L), 1,2,4-trimethylbenzene (230 μg/L), and 1,3,5-trimethylbenzene (61 μg/L) exceeding CVs.	In 1980, a French drain system was installed behind the sea wall to recover the oil. Approximately 50,000 gallons of oil were recovered. Further cleanup of groundwater contamination is being overseen by the base underground storage tank (UST) program. Reports issued in 1993 and 1994 discuss potential approaches to designing a free product recovery system for the area. In early 2002, it was reported that such a system was active at the site.	Analytical data from the Elizabeth River have not been provided to ATSDR for review. However, contaminants were only discharged to the river from this area for a limited time and the source of contamination has been remediated. Swimming is not recommended and not expected to occur much, if at all, in this area. Any exposures to soil, surface water, or sediment affected by this site would be expected to be incidental, infrequent, and of short duration. Thus, the site poses no apparent public health hazard.

Appendix A: Evaluation of Potential Public Health Hazards at Sites Under Investigation at Naval Station Norfolk (continued)

Site	Site Description/ Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities and/or Current Status	Public Health Evaluation
Site 15: Underground Oil Spill—Piers 20, 21, and 22	An intermittent diesel oil seepage from behind the sea wall near piers 20, 21, and 22 was detected in 1979. Contaminants were thought to reach the Elizabeth River, and the soils behind the sea wall were found to be contaminated with oil. Other releases of petroleum products from fuel distribution facilities in this area have also occurred over the years.	**Groundwater:** In approximately 20 1991 samples, concentrations of benzene (4.4 μg/L), naphthalene (588 μg/L), 1,2,4-trimethylbenzene (284 μg/L), and 1,3,5-trimethylbenzene (30 μg/L) exceeded CVs. During sampling, free product up to 1.7 feet thick was observed.	Around 1980, contaminated soils were removed. Groundwater remediation is being overseen by the base UST program. Reports issued in 1993 and 1994 discuss potential approaches to designing a free product recovery system for the area. It was reported in early 2002 that such a system was active at the site.	Analytical data from the Elizabeth River have not been provided to ATSDR for review. However, contaminants were only discharged to the river from this area for a limited time and the source of contamination was remediated. Swimming is not recommended and not expected to occur much, if at all, in this area. Any exposures to soil, surface water, or sediment affected by this site would be expected to be incidental, infrequent, and of short duration. Thus, the site poses no apparent public health hazard.
Site 16: Chemical Fire, Building X-136	On July 18, 1979, a chemical fire occurred in Building X-136 due to the storage of incompatible chemicals, predominantly calcium hypochlorite and acids. During the fire-fighting operation, approximately 2 tons of calcium hypochlorite were flushed with water down the storm drain leading to the Elizabeth River. The Virginia State Water Control Board was notified of this event, and, reportedly, no adverse impacts to water quality were noted.	**Groundwater:** In 1995, 3 samples contained benzene (3.4 μg/L), TCE (41 μg/L), 1,2-DCE (4,400 μg/L), aluminum (22,500 μg/L), arsenic (18.8 μg/L), chromium (52.2 μg/L), iron (46,300 μg/L), lead (24.4 μg/L), manganese (603 μg/L), and vanadium (81.3 μg/L) at concentrations exceeding CVs.	An investigation was conducted in 2001, but results are not yet available.	Groundwater does not pose a public health hazard because there are no nearby wells and therefore no exposure to any site-related contamination. Any exposures to other media at or near the site would have been sufficiently limited that adverse health effects would not be expected, and therefore exposures to media other than groundwater pose no apparent public health hazard.
Site 17: Chemical Fire, Building SDA-215	On August 12, 1981, there was a chemical fire in cell 6 of Building SDA-215 due to the storage of incompatible chemicals, predominantly calcium hypochlorite and acids. The fire and fire-fighting operation reportedly caused significant site contamination.	**Soil:** Two 1996 samples contained only arsenic (0.77 mg/kg) at levels exceeding its CV. **Groundwater:** One 1995 sample did not contain any contaminants at concentrations exceeding CVs.	After the fire, remaining hazardous chemicals were removed, and adjacent contaminated soils were excavated and disposed of off site. On the basis of a 2001 Closeout Report, no further action will be taken at the site.	Soil contaminated by the fire was removed and the levels of arsenic present afterward are as low as naturally-occurring levels of arsenic present in soil in the area. Soil poses no apparent public health hazard because any exposure to soil contamination before it was remediated would have been sufficiently limited that adverse health effects would not be expected. Groundwater poses no public health hazard because there are no nearby wells.

Appendix A: Evaluation of Potential Public Health Hazards at Sites Under Investigation at Naval Station Norfolk (continued)

Site	Site Description/ Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities and/or Current Status	Public Health Evaluation
Site 18: Former NM Hazardous Waste Storage Area	This site, north of Site 2, was used from 1975 until 1979 to store drums of hazardous waste. The waste consisted primarily of waste oil, metal plating solutions and sludges, acids, organic solvents, and paint stripping solutions. There were significant leaks and spills of waste oil and hazardous wastes in 1979.	**Soil:** Two 1995 samples contained benzo(a)pyrene (0.38 mg/kg) and arsenic (20.2 mg/kg) at concentrations exceeding CVs.	Contaminated soils were excavated and placed in piles on the site, then landfilled with VDOH approval. In addition, a monitoring program was implemented. An investigation of this site was conducted in 2001, but results are not yet available.	Soil poses no apparent public health hazard because public exposure to contamination would have been limited, if it occurred at all, and this type of exposure would not be expected to result in adverse health effects. No groundwater samples are available. However, groundwater contamination would not be expected to impact any wells, so this pathway poses no public health hazard.
Site 19: Buildings V-60/V-90	On April 29, 1986, an electrical switch gear in Building V-60 (a warehouse, plastics shop, and office structure) caught fire. The fire spread to an adjacent storage structure, Building V-90. Transformers containing PCBs ruptured from the heat, and PCB contamination (as well as dioxins and furans, by-products of the combustion of PCBs) was spread by the smoke. Both buildings contained asbestos insulation. There was also formerly a beryllium grinding area and an instrument dial painting facility in Building V-60 (see Site 11, the instrument repair shop drains).	**Air:** Samples collected on-site before and during remediation contained levels of radon (10.8 pCi/L) and PCBs (1.01 $\mu g/m^3$) exceeding screening values. **Soil:** 1988 soil samples collected before site remediation contained levels of arsenic (20 mg/kg), benzo(a)pyrene (150 mg/kg), benzo(a)anthracene (150 mg/kg), benzo(b)flouranthene (200 mg/kg), benzo(k)flouranthene (170 mg/kg), chrysene (170 mg/kg), indeno(1,2,3-cd)pyrene (75 mg/kg), and TCE (110 mg/kg) exceeding CVs.	Shortly after the fire, efforts were made to decontaminate the buildings and their contents. After additional contamination assessment, site remediation continued until 1991. This work included the removal of contaminants, building demolition, rubble removal, and ground treatment. No further action is planned at the site.	There has been no public access to the site since the fire. Thus, on-site contamination poses no public health hazard. There are no wells near the site, so groundwater poses no public health hazard. No adverse health effects resulting from smoke from the fire have been reported. However, ambient air data were not collected during the fire.

Appendix A: Evaluation of Potential Public Health Hazards at Sites Under Investigation at Naval Station Norfolk (continued)

Site	Site Description/ Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities and/or Current Status	Public Health Evaluation
Site 20: Building LP-20 Site	A portion of Building LP-20 (which now houses the Public Works Command's Transportation Department) was used beginning in the early 1940s for aircraft engine repair, including cleaning and metal plating. There was a fuel storage area south of the building. Numerous spills of wastewater, petroleum products, and other chemicals have occurred, including as a result of damage to piping that transfers waste from on-site activities to the base wastewater treatment plant. There were also releases of JP-5 aviation fuel and cyanide from underground pipelines in the area. Nearly the entire site is paved. The Bousch Creek culvert reportedly serves as a conduit for the migration of shallow groundwater from this area to Willoughby Bay.	**Soil:** 1991 samples collected as part of an interim RI contained toluene (55,000 μg/L) at concentrations exceeding CVs. Eleven soil samples collected for the RI in 1995 contained benzo(a)pyrene (0.61 mg/kg), benzo(a)anthracene (2.2 mg/kg), benzo(b)flouranthene (1.3 mg/kg), dibenz(a,h)anthracene (0.1 mg/kg), arsenic (49.7 mg/kg), and iron (42,900 mg/kg) at concentrations exceeding CVs. Samples did not reveal one major, discrete source of contamination. **Groundwater:** Sampling was conducted from 1986 to 1991 in various parts of the site to evaluate known releases and the extent of associated contamination. In the 1980s, more than 18 monitoring wells contained free product. In 1988 and 1990 samples, contaminants detected at concentrations exceeding CVs included benzene (370 μg/L), toluene (4,400 μg/L), and TCE (54,000 μg/L). During the RI, in 1995 and 1996, more than 20 samples from shallow groundwater in the Columbia Aquifer were collected. The samples contained the following contaminants at levels exceeding CVs: chloromethane (24 μg/L), chloroethane (690 μg/L), vinyl chloride (15,000 μg/L), 1,1-DCE (3,600 μg/L), 1,1-dichloroethane (1,300 μg/L), 1,2-DCE (28,000 μg/L), 1,2-DCA (120 μg/L), 1,1,1-TCA (560 μg/L), 1,1,2-trichloroethane (1,1,2-TCA) (53 μg/L), TCE (44,000 μg/L), chloroform (220 μg/L), benzene (860 μg/L), toluene (1,200 μg/L), B2EHP (100 μg/L), antimony (79.2 μg/L), arsenic (57.6 μg/L), cadmium (8.4 μg/L), chromium (41.7 μg/L), iron (95,800 μg/L), lead (70.3 μg/L), manganese (4,270 μg/L), and vanadium (113 μg/L). Eight deep groundwater samples from the Yorktown Aquifer collected during the RI contained vinyl chloride (50 μg/L), 1,1-DCE (4 μg/L), 1,2-DCE (960 μg/L), TCE (110 μg/L), benzene (19 μg/L), arsenic (69.3 μg/L), chromium (40.5 μg/L), iron (66,100 μg/L), lead (102 μg/L), manganese (639 μg/L), and vanadium (59 μg/L) at levels above CVs. During baseline sampling before the groundwater treatment system started operating in 1998, benzene (12 μg/L), chloroethane (84 μg/L), 1,1-DCE (1,800 μg/L), cis-1,2-DCE (12,000 μg/L), trans-1,2-DCE (250 μg/L), PCE (6 μg/L), 1,2,4-trichlorobenzene (20 μg/L), TCE (20,000 μg/L), and vinyl chloride (6,400 μg/L) were detected at concentrations exceeding CVs in the shallow aquifer, while 1,1-DCE (70 μg/L), cis-1,2-DCE (1,100 μg/L), TCE (3,500 μg/L), and vinyl chloride (260 μg/L) exceeded CVs in the deep aquifer. While concentrations of some VOCs temporarily rose after the system started operating, 1999-2001 samples revealed lower levels of the VOCs than the 1998 samples (except chloroethane [310 μg/L], chloroform [6.7 μg/L], and carbon tetrachloride [2 μg/L] in the shallow aquifer and 1,1-DCE [1,200 μg/L], vinyl chloride [660 μg/L], and methylene chloride [8 μg/L] in the deep aquifer).	Three groundwater recovery/treatment systems designed to recover free product operated from the mid- to late 1980s until approximately 1995. An RI and FS for the site was completed in 1996. An AS/SVE system designed to address groundwater contaminated with VOCs began operating in April 1998. Long-term groundwater monitoring is underway.	Soil poses no apparent public health hazard because any public exposures would be sufficiently limited (incidental, infrequent, and brief) that no health effects would be expected. Groundwater poses no public health hazard because there are no wells near the site.

Appendix A: Evaluation of Potential Public Health Hazards at Sites Under Investigation at Naval Station Norfolk (continued)

Site	Site Description/ Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities and/or Current Status	Public Health Evaluation
Site 21: Building W-316	This building was formerly used by the Navy Public Works Center for PCB storage.	**Soil:** Two soil samples analyzed for pesticides and PCBs in 1995 did not contain any at levels above CVs, but previous samples reportedly contained concentrations of PCBs reaching 560 mg/kg. Soil samples collected during the 1998 soil excavation contained up to 22 mg/kg Aroclor-1260, but all soil containing more than 10 mg/kg of PCBs was removed from the site in 1998. **Groundwater:** One 1995 samples did not contain detectable levels of pesticides or PCBs.	In March 1998, PCB-contaminated soil was excavated from an approximately 10,000 square foot area and disposed of off site. Confirmatory sampling was performed and no further activities are planned.	Soil poses no public health hazard because there is no expected public exposure. Access to the base is restricted and the site is fenced. Groundwater poses no public health hazard because no contamination has been detected.
Site 22: Camp Allen Salvage Yard	This 27-acre site, located between Areas A and B of the Camp Allen Landfill, was used from the 1940s until 1995 for disposal and salvaging of scrap materials. Activities conducted on site included burning, metal smelting, and storage and management of equipment, transformers, chemicals, and petroleum products. A transformer damaged by a forklift spilled PCBs in 1989 and a preliminary cleanup was conducted at that time. All the old structures and the storage areas at the site have been removed.	**Soil:** Sixteen 1996 surface soil samples contained the following contaminants at concentrations exceeding their CVs: benzo(a)anthracene (3.4 mg/kg), benzo(a)pyrene (3.1 mg/kg), benzo(b)fluoranthene (4.5 mg/kg), dibenzo(a,h)anthracene (0.51 mg/kg), indeno(1,2,3-c,d)pyrene (2.2 mg/kg), 4,4'-DDD (6.9 mg/kg), 4,4'-DDT (17 mg/kg), dieldrin (1 mg/kg), heptachlor epoxide (0.3 mg/kg), Aroclor-1248 (13 mg/kg), Aroclor-1254 (22 mg/kg), Aroclor-1260 (14,000 mg/kg), antimony (65.7 mg/kg), arsenic (16.4 mg/kg), cadmium (142 mg/kg), chromium (338 mg/kg), copper (5,390 mg/kg), cobalt (4,170 mg/kg), iron (157,000 mg/kg), and lead (1,910 mg/kg). **Groundwater:** Four 1996 samples from the shallow aquifer contained B2EHP (21 μg/L), antimony (14.6 μg/L), arsenic (283 μg/L), and iron (30,400 μg/L) at concentrations exceeding CVs. Fifteen 1996 Geoprobe samples of shallow groundwater analyzed for selected VOCs contained levels of benzene (39 μg/L), 1,1-DCE (15 μg/L), and cis-1,2-DCE (1,500 μg/L) exceeding CVs. **Surface Water/Sediment:** In 1996, four surface water samples taken from two drainage features contained levels of B2EHP (56 μg/L), TCE (11 μg/L), arsenic (6.9 μg/L), and cadmium (6.2 μg/L) exceeding CVs. In three sediment samples collected concurrently, the following contaminants were detected at concentrations exceeding their CVs: benzo(a)anthracene (2.9 mg/kg), benzo(a)pyrene (2.7 mg/kg), benzo(b)fluoranthene (4 mg/kg), indeno(1,2,3-c,d)pyrene (3 mg/kg), Aroclor-1260 (6.1 mg/kg), arsenic (21.3 mg/kg), and cadmium (11.1 mg/kg).	In 1994, a Preliminary Assessment/Site Inspection report for this site was issued. In 1998, a removal action addressing PCB-contaminated soil was conducted. An RI and risk assessment for the site were completed in 1999. The removal of hot spots of metal and PCB soil contamination will be conducted from 2001 to 2002. A sediment removal action is also planned. The Camp Allen Landfill groundwater treatment systems are expected to address groundwater contamination at this site. A Proposed Remedial Action Plan calling for one foot of soil cover to be placed over the entire site has been drafted, as has an FS. The Navy plans to convert the site to ball fields and other recreational facilities, and a Virginia Department of Transportation highway connector project is expected to affect the site.	Soil, surface water, and sediment pose no apparent public health hazard because public exposures, if any, to soil and drainage features at the site would be unusual, and limited exposures to the detected levels of contaminations would not be expected to cause adverse health effects. There are no wells downgradient of the site. However, contaminants have reportedly been transported along the bedding of water pipelines that run through the site. These contaminants may leach into the pipes and affect the taps that they serve. Because these taps have not been sampled, groundwater poses an indeterminate public health hazard.

Appendix A: Evaluation of Potential Public Health Hazards at Sites Under Investigation at Naval Station Norfolk (continued)

Site	Site Description/ Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities and/or Current Status	Public Health Evaluation
		Site-Screening Areas (SSAs)		
SSA 1: Q-72 Sandblast Area	Originally identified as Solid Waste Management Unit (SWMU) 4, this half-acre site has been used for sandblasting barges since 1972. A NPDES permit governs runoff from the site, which is adjacent to the Elizabeth River.	**Soil:** In 4 1995 samples, no pesticides or PCBs were detected, but arsenic (11.7 mg/kg) and iron (25,800 mg/kg) were present at concentrations exceeding CVs. **Groundwater:** No pesticides or PCBs were detected in a 1996 sample.	Further investigation of the site was planned for the summer of 2001.	Soil poses no apparent public health hazard. The levels of arsenic and iron detected do not cause adverse health effects to individuals with short-term and infrequent exposures, the only types expected. Groundwater poses no public health hazard because there are no nearby wells that supply drinking water.
SSA 2: V-28 Waste Pit	There was formerly a subsurface concrete pad used for storage of metal-plating shop waste at this site, also known as SWMU 6. Plating operations ceased in 1987. The site, approximately 200 feet north of Willoughby Bay, is now covered with approximately 6 inches of concrete.	**Groundwater:** A 1995 sample analyzed for VOCs, SVOCs, and metals contained only cadmium (14.3 μg/L), chromium (1,760 μg/L), and iron (15,600 μg/L) at concentrations exceeding CVs.	In the 1980s, the building was demolished and contaminated soil was removed and replaced with clean fill. An SI was completed in 1998, and a Supplemental Investigation Report is being developed. Monitoring is also underway to assess the extent of natural attenuation of contaminants that has occurred.	Neither soil nor groundwater pose a public health hazard because there is no public exposure to the site and there are no nearby wells. For a public health evaluation of exposure to surface water and sediment in Willoughby Bay, see Site 13, located between this site and the bay.
SSA 3: Fire-fighting School	Navy personnel have been trained to extinguish various types of fires in this area, also known as SWMU 8. Petroleum staining of the soil at the site is visible in aerial photographs dating back to 1949. Drainage basins collect runoff from the area and access to the site is restricted. In 1991 and 1992, portions of the site were reconstructed and a slurry wall was constructed between the area formerly used and the area still used. SSA 3 includes the area no longer used, which is covered with asphalt and concrete. The area still used will be investigated separately.	**Soil:** Only arsenic (11.9 mg/kg) was present at concentrations exceeding CVs in 5 1995 samples. **Groundwater:** Benzene (220 μg/L) and 1,2-dichloroethane (5.3 μg/L) were detected at concentrations exceeding CVs in 2 1995 samples.	Six USTs have been removed from the SSA. The Navy plans to close the area under its UST program, perform appropriate sampling, and cap the site with asphalt. Additional groundwater sampling was conducted in August 1999 and a Closeout Report for the site has been drafted.	Because there is no public exposure to them, soil and groundwater pose no public health hazard. Access to the site is restricted, preventing exposure to soil, and there is no exposure to groundwater because there are no nearby wells.

Appendix A: Evaluation of Potential Public Health Hazards at Sites Under Investigation at Naval Station Norfolk (continued)

Site	Site Description/ Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities and/or Current Status	Public Health Evaluation
SSA 4: NM-37 Area	This site is near Building NM-37, which is used for vehicle maintenance. It was originally identified as SWMUs 12 and 16. It includes three areas used for hazardous waste storage, two of which held fuel, hydraulic fluids, solvents, and paints.	**Soil:** Eight surface soil samples collected in 1995 and 1996, analyzed for VOCs, SVOCs, and metals, contained only arsenic (273 mg/kg) at concentrations exceeding CVs. **Groundwater:** One 1995 groundwater sample analyzed for the same parameters at the soil samples contained only chloroform (33 µg/L) at a level exceeding its CV.	After 1998 sampling, the results of which are not yet available, access controls were recommended. A streamlined risk assessment of this site was initiated in 2001.	Soil poses no apparent public health hazard because infrequent, incidental, and brief contact with contaminants, the only anticipated type of public exposure, would not be expected to cause adverse health effects. Groundwater poses no public health hazard because there are no nearby, downgradient wells.
Areas of Concern (AOCs)				
AOC 1: Building Z-309	This site includes two areas near Building Z-309, SWMUs 2 and 3. Salvage fuel boilers in Building Z-309 burned municipal waste until 1986. There are USTs and aboveground storage tanks (ASTs) in the area. The site includes a former storage area for ash from boiler operations and storage area for oils and lubricants, both demolished in 1997. Part of the site has been made into a paved parking lot and the other part was covered with topsoil and reseeded.	**Soil:** In 9 1995 and 1996 samples, antimony (41.5 mg/kg), arsenic (42.5 mg/kg), cadmium (108 mg/kg), lead (1,320 mg/kg), benzo(a)anthracene (1.5 mg/kg), benzo(a)pyrene (4.2 mg/kg), benzo(b)flouranthene (4.0 mg/kg), dibenzo(a,h)anthracene (0.41 mg/kg), and indeno(1,2,3-cd)pyrene (2.3 mg/kg) were detected at concentrations exceeding CVs. **Groundwater:** One sample collected in 1995 did not contain any contaminants at levels above CVs.	Waste was removed and the area was covered with pavement and/or topsoil and vegetation after samples were collected. In May 2000, a Closeout Report stating that no further action would be required at the site was approved.	Any public exposures to soil at the site would be expected to be incidental and infrequent. In such circumstances, exposures to the detected levels of contaminants in surface soil would not be expected to cause adverse health effects. Thus, soil poses no apparent public health hazard. Groundwater poses no public health hazard because there are no drinking water wells near the site.
AOC 2: Marine Air Cargo (MAC) Area	Historical aerial photographs indicate that this area was used as a solid waste and fill disposal area by 1949. The site, through which a drainage ditch runs, is comprised of the areas also known as SWMUs 9 and 10. Only personnel performing aircraft maintenance are permitted in the SWMU 9 portion of the site. SWMU 10 is entirely vegetated.	**Soil:** Benzo(a)pyrene (0.48 mg/kg), arsenic (7.8 mg/kg), and iron (24,300 mg/kg) were present at concentrations exceeding CVs in 14 1995 and 1996 samples. **Groundwater:** Four 1995 samples contained arsenic (49 µg/L), beryllium (11 µg/L), iron (107,000 µg/L), manganese (9,100 µg/L), nickel (276 µg/L), and vanadium (54 µg/L) at concentrations exceeding CVs.	Groundwater investigations were conducted at the site in 1999 and 2000, and a Supplemental Site Investigation Report is being drafted.	Soil poses no apparent public health hazard because the detected levels of benzo(a)pyrene, arsenic, and iron would not cause adverse health effects under limited exposure scenarios, the only ones expected for members of the public. Groundwater poses no public health hazard because there are no nearby, downgradient drinking water wells.

Appendix A: Evaluation of Potential Public Health Hazards at Sites Under Investigation at Naval Station Norfolk (continued)

Site	Site Description/ Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities and/or Current Status	Public Health Evaluation
AOC 3: CEP Area	This site, near the Elizabeth River, was originally identified as SWMUs 28, 32, 33, 34, 35, and 42. It includes storage areas (within SWMUs 28 and 42) for large objects, such as tractor trailers and equipment awaiting shipment. Also included are areas used for disposal of solid waste and, in some cases, fill (within SWMUs 32, 33, and 34, 35, and 42). Parts of the site are used for parking, while others are vegetated or paved.	**Soil:** Arsenic (15.1 mg/kg) and benzo(a)pyrene (0.31 mg/kg) have been detected in four surface soil samples collected in 1995 and 1996. **Groundwater:** Arsenic (37 μg/L), iron (32,100 μg/L), manganese (2,300 μg/L), thallium (3.7 μg/L), and B2EHP (40 μg/L) have been detected at concentrations exceeding CVs in groundwater samples. **Surface Water/Sediment:** In 3 1996 surface water and sediment samples from the ditch at SWMU 34, concentrations of B2EHP (17 μg/L), antimony (15 μg/L), arsenic (2.2 μg/L), and lead (45 μg/L) exceeded CVs in surface water, and levels of benzo(a)pyrene (0.12 mg/kg), benzo(a)anthracene (1.6 mg/kg), arsenic (17.3 mg/kg), cadmium (15.3 mg/kg), chromium (421 mg/kg), iron (32,600 mg/kg), lead (637 mg/kg) exceeded CVs in sediment.	In May 2000, a Closeout Report and Streamlined Risk Assessment Report stating that no further action would be required at the site were approved.	Because there is little, if any, public exposure to surface soil or the ditch at this site and detected levels of contaminants in soil, surface water, and sediment would not be expected to cause adverse health effects under limited exposure scenarios, these media pose no apparent public health hazard. Groundwater poses no public health hazard because the only nearby wells are not downgradient and are not used for drinking water.
AOC 4: Q-50 PWC Accumulation Area	At this site, hazardous waste generated at the base was stored for up to 90 days and processed. The area was also used for temporary stockpiling of railroad ties and metal debris. The area is also known as SWMU 14.	**Soil:** Analysis of 6 1995 and 1996 samples revealed benzo(a)pyrene (2.5 mg/kg), benzo(b)flouranthene (3.5 mg/kg), dibenz(a,h)anthracene (0.86 mg/kg), indeno(1,2,3-cd)pyrene (2.3 mg/kg), Aroclor-1254 (3.1 mg/kg), antimony (55.4 mg/kg), arsenic (28.4 mg/kg), cadmium (33.4 mg/kg), copper (12,300 mg/kg), iron (77,000 mg/kg), and lead (1,550 mg/kg) at concentrations exceeding CVs. **Groundwater:** Analysis of 3 samples in 1996 revealed levels of pentachlorophenol (3 μg/L), B2EHP (24 μg/L), benzo(a)anthracene (1 μg/L), benzo(b)flouranthene (1 μg/L), carbazole (15 μg/L), Aroclor-1242 (30 μg/L), Aroclor-1254 (6.4 μg/L), antimony (39.7 μg/L), arsenic (2.6 μg/L), barium (3,310 μg/L), cadmium (6.7 μg/L), chromium (35.2 μg/L), iron (20,200 μg/L), lead (496 μg/L), and vanadium (120 μg/L) exceeding CVs.	Additional investigations of the site were conducted from 1998 to 2001. Sediment sampling is planned, and an RI is being drafted.	Because the public is not allowed on this site, any public exposures would be rare and would not be expected to result in adverse health effects. Thus, soil poses no apparent public health hazard. Groundwater poses no public health hazard because there are no wells in the vicinity of the site.

Appendix A: Evaluation of Potential Public Health Hazards at Sites Under Investigation at Naval Station Norfolk (continued)

Site	Site Description/ Waste Disposal History	Investigation Results/ Environmental Monitoring Results	Corrective Activities and/or Current Status	Public Health Evaluation
AOC 5: CD Area Behind Compost Yard	Aerial photographs from 1987 and 1991 suggest that this area might have been used to dispose of construction materials. An 8-foot high soil berm was subsequently constructed over top of the disposal area. The site is also known as SWMU 38.	**Soil:** One 1996 sample contained arsenic (76.8 mg/kg), iron (35,400 mg/kg), benzo(a)pyrene (1.7 mg/kg), benzo(b)flouranthene (1.8 mg/kg), and indeno(1,2,3-cd)pyrene (1.2 mg/kg) at concentrations exceeding CVs. **Groundwater:** Manganese (534 μg/L), thallium (4.4 μg/L), and B2EHP (21 μg/L) were detected at concentrations exceeding CVs in 4 1996 samples.	An investigation of this site was conducted in 2001, but results are not yet available.	The metals and PAHs present in soil were detected at concentrations that would not result in adverse health effects if exposures were short, infrequent, and incidental. Since these are the only types of public exposures that would occur, soil poses no apparent public health hazard. Because there are no wells near this site, groundwater poses no public health hazard.
AOC 6: Open Dump and Disposal Area at Boundary of Camp Allen Landfill	Background information about this site, originally identified as SWMU 39, is not available.	Analytical data from sampling conducted in 2000 and 2001 are not yet available.	An investigation of this site was conducted in 2000 and 2001, but results are not yet available.	Data enabling a public health evaluation are not yet available.
AOC 7: MCA-603 Pits	Aerial photographs of this site, also known as SWMU 40, indicate that it formerly contained two pits, one of which held liquid. The area is currently used for recreation and contains several baseball diamonds and a soccer field.	**Soil:** Four 1996 samples contained only arsenic (2.2 mg/kg) at concentrations exceeding its CV. **Groundwater:** Six 1996 samples contained only antimony (258 μg/L) and thallium (3.8 μg/L) at concentrations exceeding CVs.	In May 2000, a Closeout Report stating that no further action would be required at the site was approved.	The pits formerly at this site are no longer present. The detected levels of arsenic may be naturally-occurring and do not result in adverse health effects under expected exposure scenarios. Thus, soil does not pose a public health hazard. Groundwater does not pose a public health hazard because there are no nearby, downgradient wells.
AOC 8: Disposal Area, CA-99 Golf Course	This former disposal area next to the CA-99 golf course is currently used for recreation and contains a pond. The site is also known as SWMU 41.	**Soil:** Arsenic (3.2 mg/kg) and benzo(a)pyrene (0.24 mg/kg) were found in three 1998 samples at concentrations exceeding CVs. **Groundwater:** Cadmium (3 μg/L), manganese (1,970 μg/L), and thallium (1.7 μg/L) were detected at concentrations exceeding CVs in three 1998 samples from the shallow aquifer.	In May 2000, a Closeout Report stating that no further action would be required at the site was approved.	The contaminants detected in soil at this site were sufficiently low that they would not cause adverse health effects under expected exposure scenarios, which would be infrequent, incidental, and of short duration. There are no nearby, downgradient wells and therefore no exposure to groundwater near the site. Thus, groundwater poses no public health hazard.

Sources: Baker 1993, 1994c, 1995a, b, 1996a, b, c; CH2MHILL 1997b, 1998a, b, 1999a, b, 2000a, b, c, d, e, 2001a, b, c; CLEAN 1999; Groundwater Technology Government Services 1994; Environmental Science & Engineering 1994; FFA 1999; Johnson 2002; Malcolm Pirnie 1998; Naval Station Norfolk 2000; Sparks and Rakowski n.d.; STORET 2001; VDEQ-WDG 1987; VDEQ-RS 2000, 2001; Versar 1990, 1991, 1993.

Appendix A: Evaluation of Potential Public Health Hazards at Sites Under Investigation at Naval Station Norfolk (continued)

Abbreviations:

AOC	area of concern	RI	remedial investigation
AS/SVE	air sparging/soil vapor extraction	ROD	record of decision
B2EHP	bis(2-ethylhexyl)phthalate	RRR	relative risk ranking
CV	comparison value	SI	site investigation
1,2-DCA	1,2-dichloroethane	SSA	site-screening area
1,1-DCE	1,1-dichloroethene	SVOC	semi-volatile organic compound
1,2-DCE	1,2-dichloroethene	SWMU	solid waste management unit
FS	feasibility study	1,1,1-TCA	1,1,1-trichloroethane
IRP	Installation Restoration Program	1,1,2-TCA	1,1,2-trichloroethane
mg/kg	milligrams per kilogram	1,1,2,2-TCA	1,1,2,2-tetrachloroethane
NPDES	National Pollutant Discharge Elimination System	TCE	trichloroethylene
OU	operable unit	µg/L	micrograms per liter
PAH	polycyclic aromatic hydrocarbon	$\mu g/m^3$	micrograms per cubic meter
PCB	polychlorinated biphenyl	UST	underground storage tank
PCE	tetrachloroethylene	VDOH	Virginia Department of Health
pCi/g	picoCuries per gram	VDEQ	Virginia Department of Environmental Quality
pCi/L	picoCuries per liter	VOC	volatile organic compound

APPENDIX B: Glossary

Absorption: How a chemical enters a person's blood after the chemical has been swallowed, has come into contact with the skin, or has been breathed in.

Acute Exposure: Contact with a chemical that happens once or only for a limited period of time. ATSDR defines acute exposures as those that might last up to 14 days.

Adverse Health Effect: A change in body function or the structures of cells that can lead to disease or health problems.

ATSDR: The **A**gency for **T**oxic **S**ubstances and **D**isease **R**egistry. ATSDR is a federal health agency in Atlanta, Georgia, that deals with hazardous substances and waste site issues. ATSDR gives people information about harmful chemicals in their environment and tells people how to protect themselves from coming into contact with chemicals.

Background Level: An average or expected amount of a chemical in a specific environment. Or, amounts of chemicals that occur naturally in a specific environment.

Biota: Used in public health, things that humans would eat, including animals, fish and plants.

Cancer: A group of diseases which occur when cells in the body become abnormal and grow, or multiply, out of control.

Cancer Slope Factor (CSF): Used to define the relationship between exposure doses and the likelihood of an increased risk of developing cancer over a lifetime. CSFs are developed using data from animal or human studies and represent the upper-bound estimate of the probability of developing cancer at a defined level of exposure and tend to be very conservative (i.e., overestimate the actual risk) in order to account for a number of uncertainties in the data.

Cancer Risk Evaluation Guide (CREG): An estimated contaminant concentration in water, soil, or air that would be expected to cause no more than one excess cancer in a million persons exposed over a 70-year lifetime, according to U.S. Environmental Protection Agency (EPA) estimates. As ATSDR's most conservative comparison value, the CREG merits special attention. Note that this does *not* mean that exposures equivalent to the CREG are actually expected to *cause* one excess cancer in a million persons exposed over a lifetime. Nor does it mean that every person in an exposed population of one million has a 1-in-a-million chance of developing cancer from the specified exposure. Although ATSDR CREGs continue to be useful devices for screening cancer-causing substances at a site, they cannot be used to predict cancer incidence rates at a site. Furthermore, the exposure assumptions on which EPA's cancer risk estimates and ATSDR's CREGs are based (i.e., essentially lifetime exposure) seldom apply at contaminated sites.

Chronic Exposure: A contact with a substance or chemical that happens over a long period of time. ATSDR considers exposures of more than one year to be *chronic*.

Completed Exposure Pathway: See **Exposure Pathway.**

Comparison Value (CV): Concentrations or the amount of substances in air, water, food, and soil that are unlikely, upon exposure, to cause adverse health effects. Comparison values are used by health assessors to select which substances and environmental media (air, water, food and soil) need additional evaluation while health concerns or effects are investigated.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA): **CERCLA** was put into place in 1980. It is also known as **Superfund**. This act concerns releases of hazardous substances into the environment, and the cleanup of these substances and hazardous waste sites. ATSDR was created by this act and is responsible for looking into the public health issues related to hazardous waste sites.

Concern: A belief or worry that chemicals in the environment might cause harm to people.

Concentration: How much or the amount of a substance present in a certain amount of soil, water, air, or food.

Contaminant: See **Environmental Contaminant.**

Dermal Contact: A chemical getting onto your skin. (see **Route of Exposure**).

Dose: The amount of a substance to which a person might be exposed, usually on a daily basis. Dose is often explained as "amount of substance(s) per body weight per day."

Duration: The amount of time (days, months, years) that a person is exposed to a chemical.

Environmental Contaminant: A substance (chemical) that gets into a system (person, animal, or the environment) in amounts higher than that found in **Background Level**, or what would be expected.

Environmental Media: Usually refers to the air, water, and soil in which chemicals of interest are found. Sometimes refers to the plants and animals that are eaten by humans. **Environmental Media** is the second part of an **Exposure Pathway**.

Environmental Media Evaluation Guide (EMEG): A concentration of a contaminant in water, soil, or air that is unlikely to be associated with any appreciable risk of deleterious noncancer effects over a specified duration of exposure. EMEGs are derived from ATSDR Minimal Risk Levels by factoring in default body weights and ingestion rates. Separate EMEGs are computed for acute ($\leq$ 14 days), intermediate (15-364 days), and chronic ($\geq$365 days) exposures.

U.S. Environmental Protection Agency (EPA): The federal agency that develops and enforces environmental laws to protect the environment and the public's health.

Epidemiology: The study of the different factors that determine how often, in how many people, and in which people disease will occur.

Exposure: Coming into contact with a chemical substance. (For the three ways people can come in contact with substances, see **Route of Exposure**.)

Exposure Assessment: The process of finding the ways people come in contact with chemicals, how often and how long they come in contact with chemicals, and the amounts of chemicals with which they come in contact.

Exposure Pathway: A description of the way that a chemical moves from its source (where it began) to where and how people can come into contact with (or get exposed to) the chemical.
ATSDR defines an exposure pathway as having five parts:
1. Source of Contamination,
2. Environmental Media and Transport Mechanism,
3. Point of Exposure,
4. Route of Exposure, and
5. Receptor Population.

When all five parts of an exposure pathway are present, it is called a **Completed Exposure Pathway**. Each of these five terms is defined in this glossary.

Frequency: How often a person is exposed to a chemical over time; for example, every day, once a week, twice a month.

Hazardous Waste: Substances that have been released or thrown away into the environment and, under certain conditions, could be harmful to people who come into contact with them.

Health Effect: ATSDR deals only with **Adverse Health Effects** (see definition in this glossary).

Indeterminate Public Health Hazard: The category is used in public health assessments for sites where important information is lacking (missing or has not yet been gathered) about site-related chemical exposures.

Ingestion: Swallowing something, as in eating or drinking. It is a way a chemical can enter your body (See **Route of Exposure**).

Inhalation: Breathing. It is a way a chemical can enter your body (See **Route of Exposure**).

Lifetime Health Advisory (LTHA): A contaminant concentration that EPA deems protective of public health (considering the availability and economics of water treatment technology) over a lifetime (70 years) at an exposure rate of 2 liters of water per day.

LOAEL: Lowest Observed Adverse Effect Level. The lowest dose of a chemical in a study, or group of studies, that has caused harmful health effects in people or animals.

Maximum Contaminant Level (MCL): A contaminant concentration in drinking water that EPA deems protective of public health (considering the availability and economics of water treatment technology) over a lifetime (70 years) at an exposure rate of 2 liters of water per day.

Minimal Risk Level (MRL): An estimate of daily human exposure—by a specified route and length of time—to a dose of chemical that is likely to be without a measurable risk of adverse, noncancerous effects. An MRL should not be used as a predictor of adverse health effects.

National Priorities List: Part of **Superfund**, a list kept by EPA of the most serious, uncontrolled, or abandoned hazardous waste sites in the country. An NPL site needs to be cleaned up or is being looked at to see if people can be exposed to chemicals from the site.

NOAEL: No Observed Adverse Effect Level. The highest dose of a chemical in a study, or group of studies, that did not cause harmful health effects in people or animals.

No Apparent Public Health Hazard: The category is used in ATSDR's public health assessments for sites where exposure to site-related chemicals might have occurred in the past or is still occurring but the exposures are not at levels expected to cause adverse health effects.

No Public Health Hazard: The category is used in ATSDR's public health assessments for sites where there is evidence of an absence of exposure to site-related chemicals.

Plume: A line or column of air or water containing chemicals moving from the source to areas further away. A plume can be a column or clouds of smoke from a chimney or contaminated underground water sources or contaminated surface water (such as lakes, ponds, and streams).

Point of Exposure: The place where someone can come into contact with a contaminated environmental medium (air, water, food, or soil). For example: the area of a playground that has contaminated dirt, a contaminated spring used for drinking water, the location where fruits or vegetables are grown in contaminated soil, or the backyard area where someone might breathe contaminated air.

Population: A group of people living in a certain area; or the number of people in a certain area.

Public Health Assessment (PHA): A report or document that looks at chemicals at a hazardous waste site and tells if people could be harmed from coming into contact with those chemicals. The PHA also tells if possible further public health actions are needed.

Public Health Hazard: The category is used in PHAs for sites that have certain physical features or evidence of chronic, site-related chemical exposure that could result in adverse health effects.

Public Health Hazard Category: PHA categories given to a site which tell whether people could be harmed by conditions present at the site. Each are defined in the glossary. The categories are:

1. Urgent Public Health Hazard
2. Public Health Hazard
3. Indeterminate Public Health Hazard
4. No Apparent Public Health Hazard
5. No Public Health Hazard

Receptor Population: People who live or work in the path of one or more chemicals, and who could come into contact with them (See **Exposure Pathway**).

Reference Dose (RfD): An estimate, with safety factors (see **safety factor**) built in, of the daily, life-time exposure of human populations to a possible hazard that is <u>not</u> likely to cause harm to the person.

Reference Dose Media Evaluation Guide (RMEG): The concentration of a contaminant in air, water, or soil that corresponds to EPA's RfD for that contaminant when default values for body weight and intake rates are taken into account.

Risk-Based Concentration (RBC): EPA Region III combines reference doses and cancer slope factors with "standard" exposure scenarios to calculate risk-based concentrations, which are chemical concentrations corresponding to fixed levels of risk (i.e., a hazard quotient of 1, or lifetime cancer risk of 10^{-6}, whichever occurs at a lower concentration) in water, air, fish tissue, and soil.

Route of Exposure: The way a chemical can get into a person's body. There are three exposure routes:
- breathing (also called inhalation),
- eating or drinking (also called ingestion), and
- getting something on the skin (also called dermal contact).

Safety Factor: Also called **Uncertainty Factor**. When scientists don't have enough information to decide if an exposure will cause harm to people, they use "safety factors" and formulas in place of the information that is not known. These factors and formulas can help determine the amount of a chemical that is not likely to cause harm to people.

SARA: The Superfund Amendments and Reauthorization Act in 1986 amended the **Comprehensive Environmental Response, Compensation, and Liability Act** (CERCLA) and expanded the health-related responsibilities of ATSDR. CERCLA and SARA direct ATSDR to look into the health effects from chemical exposures at hazardous waste sites.

Source (of Contamination): The place where a chemical comes from, such as a landfill, pond, creek, incinerator, tank, or drum. Contaminant source is the first part of an **Exposure Pathway**.

Superfund: Another name for the **Comprehensive Environmental Response, Compensation, and Liability Act**, which created ATSDR.

Survey: A way to collect information or data from a group of people (**population**). Surveys can be done by phone, mail, or in person. ATSDR cannot do surveys of more than nine people without approval from the U.S. Department of Health and Human Services.

Synergistic effect: A health effect from an exposure to more than one chemical, where one of the chemicals worsens the effect of another chemical. The combined effect of the chemicals acting together are greater than the effects of the chemicals acting by themselves.

Toxic: Harmful. Any substance or chemical can be toxic at a certain dose (amount). The dose is what determines the potential harm of a chemical and whether it would cause someone to get sick.

Toxicology: The study of the harmful effects of chemicals on humans or animals.

Tumor: Abnormal growth of tissue or cells that have formed a lump or mass.

Uncertainty Factor: See **Safety Factor**.

Urgent Public Health Hazard: This category is used in ATSDR's public health assessments for sites that have certain physical features or evidence of short-term (less than 1 year), site-related chemical exposure that could result in adverse health effects and require quick intervention to stop people from being exposed.

Volatile Organic Compound (VOC): A substance containing carbon and different proportions of other elements, such as hydrogen, oxygen, fluorine, chlorine, bromine, sulfur, or nitrogen. VOCs easily become vapors or gases, and a significant number of them are commonly used as solvents (paint thinners, lacquer thinner, degreasers, and dry cleaning fluids).

APPENDIX C: Exposure Evaluation

Estimates of Human Exposure Doses and Determination of Health Effects

Deriving Exposure Doses

The Agency for Toxic Substances and Disease Registry (ATSDR) estimated human exposure doses from ingestion of shellfish and fish harvested from Willoughby Bay. Deriving exposure doses requires evaluating the concentrations of the contaminants to which people might have been or might be exposed and how often and for how long exposures to those contaminants occur. Together, these factors help influence individual physiological responses to contaminant exposure and potential for noncancer or cancer outcomes. In the absence of exposure-specific information, ATSDR applied several conservative assumptions to define site-specific exposures as accurately as possible for people consuming contaminated fish and shellfish.

Evaluating Potential Health Hazards

Estimated exposure doses are used to evaluate potential noncancer and cancer effects associated with contaminants detected in site media. When evaluating ***noncancer*** effects, ATSDR first compares the estimated exposure dose to standard toxicity values, including ATSDR's minimal risk levels (MRLs) and the U.S. Environmental Protection Agency's (EPA's) reference doses (RfDs), to evaluate whether adverse effects might occur. The MRLs and RfDs are estimates of daily human exposure to a substance that is likely to be without appreciable risk of adverse noncancer effects over a specified duration. The MRLs and RfDs are conservative values, based on the levels of exposure reported in the literature that represent no observed adverse effects levels (NOAELs) or lowest observed adverse effects levels (LOAELs) for the most sensitive outcome for a given route of exposure (e.g., dermal contact, ingestion). In addition, uncertainty (safety) factors are applied to NOAELs or LOAELs to account for variation in the human population and uncertainty involved in extrapolating human health effects from animal studies. If estimated exposure doses are greater than the appropriate MRL or RfD, ATSDR reviews the toxicological literature to determine the likelihood of adverse effects.

When evaluating the potential for ***cancer*** to occur, ATSDR uses cancer slope factors (CSFs) that define the relationship between exposure doses and the likelihood of an increased risk of developing cancer over a lifetime. The CSFs are developed using data from animal or human studies and often require extrapolation from high exposure doses administered in animal studies to lower exposure levels typical of human exposure to environmental contaminants. CSFs represent the upper-bound estimate of the probability of developing cancer at a defined level of exposure; therefore, they tend to be very conservative (i.e., overestimate the actual risk) in order to account for a number of uncertainties in the data used in the extrapolation.

ATSDR estimated the potential for cancer to occur using the following equation. The estimated exposure doses and CSF values for the contaminants of concern are incorporated into the equation:

Lifetime cancer risk =Estimated exposure dose (milligrams of contaminants per kilogram body weight per day [mg/kg/day]) x CSF $(mg/kg/day)^{-1}$

Although no risk of cancer is considered acceptable, because a zero cancer risk is not possible to achieve, ATSDR often uses a range of 10^{-4} to 10^{-6} estimated lifetime cancer risk (or 1 new case in 10,000 to 1,000,000 exposed persons), based on conservative assumptions about exposure, to determine whether there is a concern for cancer effects.

Estimated Exposure Dose for Consumption of Shellfish or Fish from Willoughby Bay

Shellfish and fish samples collected from Willoughby Bay over the last 30 years have contained elevated levels of PAHs, pesticides, PCBs, and metals. People consuming fish and shellfish might be exposed to these contaminants. Levels would be expected to have been at their highest prior to the mid-1970s, before Naval Station Norfolk's industrial wastewater was rerouted to an industrial wastewater treatment plant. In addition, increasing wastewater and stormwater management requirements would be expected to result in a decline in levels of contaminants reaching the bay in subsequent years.

To determine whether exposures to contaminants in shellfish or fish might be related to adverse health effects, ATSDR estimated exposure doses for people consuming these aquatic biota. We did not identify any information suggesting that subsistence fishing occurs in Willoughby Bay. In estimating to what extent people might be exposed to contaminants, we used conservative assumptions about how much fish and shellfish people eat, how often exposures occur, and for how long exposures last, as well as conservative assumptions about contaminant concentrations (i.e., that all exposures were to the highest levels of contaminants detected). These assumptions allow ATSDR to estimate the highest likely exposure dose, on the basis of our understanding of site-specific conditions, and evaluate the corresponding health effects. Although we expect that few people are regularly exposed at these levels, the conservative estimates are used to protect public health. ATSDR used the following equation and exposure assumptions to estimate exposure doses:

$$\textit{Estimated exposure dose} = \frac{C \times IR \times EF \times ED}{BW \times AT}$$

where:

C = Maximum concentration (milligrams per kilogram [mg/kg])

IR = Intake rate:
Chronic intake for adults = 0.035 kg/day (approximately five 8-ounce fish or shellfish servings/month); for children = 0.0175 kg/day (approximately five

4-ounce fish or shellfish servings/month)[3]
Acute intake for adults = 0.326 kilograms/serving (11.4 ounces);
for children = 0.170 kilograms/serving (about 6 ounces)[4]

EF = Exposure frequency: 365 days/year

ED = Exposure duration or the duration over which exposure occurs: adult = 30 years; child = 5 years

BW = Body weight: adult = 70 kg (154 pounds); child = 10 kg (22 pounds)

AT = Averaging time or the period over which cumulative exposures are averaged: 5 years or 30 years x 365 days/year for noncancer effects and 70 years (considered a lifetime) x 365 days/year for cancer effects

On the basis of estimated exposure doses and review of the relevant toxicologic literature, ***ATSDR concluded that exposures to contaminants in fish and shellfish harvested from Willoughby Bay would not be expected to result in any long-term health effects. However, acute exposure to some of the elevated levels of zinc in fish or shellfish might cause temporary decreases in serum cortisol levels or short-term gastrointestinal distress. For the most part, these concentrations were detected in oysters, but there has been no documented oyster harvest from Willoughby Bay since 1972. In 2001 samples from a range of seafood species, the detected concentrations of zinc in species other than oysters would not be expected to cause any adverse health effects.*** ATSDR's evaluation of chemical-specific exposures is detailed as follows.

Cancer

Not all of the contaminants detected in fish and shellfish from Willoughby Bay have the potential to cause cancer. ATSDR evaluated contaminants that could potentially cause cancer, including arsenic, benzo(a)pyrene, benzo(b)fluoranthene, 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, heptachlor epoxide, and PCBs/Aroclor-1254. For all contaminants, the derived lifetime cancer risk for exposure to contaminants is below levels that are likely to result in increased instances of cancer.

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[3] The estimate for adult chronic intake is based on the 90th percentile intake of recreationally-caught fish and shellfish by recreational fisherman who consumed their catch, according to data from a 1981 study of marine finfish and shellfish consumption survey in metropolitan Los Angeles (reanalyzed in 1994). ATSDR did not identify any studies reflecting intake rates of marine fish and shellfish for populations in the Mid-Atlantic area. The estimate for child chronic intake is 50% of the adult intake (EPA 1997).

[4] The estimate for adult acute intake is based on the 95th percentile fish or shellfish serving size from 1989 to 1991 United States Department of Agriculture data. The estimate for child acute intake is based on the 95th percentile fish or shellfish serving size for children aged 3 to 6 from a 1977-1978 United States Department of Agriculture food consumption survey for which data were collected by age (EPA 1997).

Noncancer

ATSDR's calculated noncancer doses assume that people were exposed to the maximum detected concentration over the entire exposure period. ATSDR used conservative assumptions about consumption rates and levels and the length of exposures. The calculated doses were then compared to ATSDR's MRLs or EPA's RfDs. Calculated noncancer doses were below the associated MRLs or RfDs for most contaminants. The exceptions are discussed below. The contaminants for which noncancer doses calculated using ATSDR's conservative assumptions exceeded MRLs or RfDs were arsenic, cadmium, mercury, thallium, and zinc. ATSDR concluded that ingestion of arsenic, cadmium, mercury, and thallium in aquatic biota from Willoughby Bay would not be expected to result in any adverse health effects and that ingestion of zinc would not be expected to result in any lasting health consequences, but might cause serum cortisol levels to decline temporarily or might cause short-term gastrointestinal distress. The calculated doses for chromium are below the RfD for chromium III, the type of chromium expected to be present in aquatic biota.

There are no MRLs or RfDs for lead. ATSDR's evaluation of the potential for adverse health effects from lead, provided below, is based on expected increases in blood lead levels, which have been shown to be correlated to adverse health effects. This evaluation concluded that adverse health effects due to consumption of lead in fish or shellfish from Willoughby Bay would not be expected.

<u>Arsenic</u>

Arsenic exists in nature in both organic and inorganic forms. Organic forms are essentially non-toxic, while inorganic forms can produce a variety of health effects. Available samples from Willoughby Bay measured total arsenic. The detected concentrations in fish and shellfish from Willoughby Bay ranged from <0.5 mg/kg in (a 1998 spot sample and 2001 samples of blue crabs, croaker, spot, oysters, and hard clams), to 1.1 mg/kg in a 1998 crab sample, to 2.5 mg/kg in a 1986 clam sample, to 3.0 mg/kg in a 1994 oyster sample. Scientific research indicates that most arsenic present in fish and shellfish is in a non-toxic organic form. According to studies, the inorganic component of arsenic accounts for 10%–20% of the total arsenic in fish and shellfish (FDA 1993a, ATSDR 2000). ATSDR's dose calculations for inorganic arsenic are based, therefore, on exposure to a conservatively estimated 20% of the maximum concentration of total arsenic detected in a sample, or 0.6 mg/kg.

ATSDR's estimated chronic dose for adults (0.0003 mg/kg/day) does not exceed the chronic MRL of 0.0003 mg/kg/day, and ATSDR's estimated chronic dose for children (0.001 mg/kg/day) only slightly exceeds the chronic MRL. Furthermore, the doses estimated based on chronic exposure to the maximum level of arsenic detected are lower than the lowest level at which health effects were reported in the scientific literature (the lowest LOAEL), 0.005 mg/kg/day. Because continuous exposures to the highest detected concentration of inorganic arsenic in fish or shellfish from Willoughby Bay is unlikely to occur, chronic exposure to arsenic is not expected to cause any adverse health effects.

The estimated acute dose of arsenic to children was estimated at 0.01 mg/kg/day, which exceeds ATSDR's provisional acute MRL (0.005 mg/kg/day). However, ATSDR's assumption that a small child is consuming an approximately 6-ounce serving of fish or shellfish in one meal (acute exposure) is very conservative. Also, the lowest LOAEL reported in the literature for acute exposure is 0.05 mg/kg/day, 10 times higher than the MRL and higher than the worst-case dose that ATSDR estimated (ATSDR 2000). Thus, adverse effects from acute exposures to arsenic are not expected.

Cadmium

Cadmium occurs naturally in the earth's crust, but it is also used to plate certain aircraft parts and in other products used at Naval Station Norfolk. The highest detected concentrations of cadmium in aquatic biota from Willoughby Bay, 6.06 mg/kg (1971) and 3.7 mg/kg (1976), have been found in oyster samples. Since 1985, all detected concentrations have been below 1 mg/kg, except in one 1987 sample, which contained 3.1 mg/kg of cadmium. A 2001 VDEQ oyster sample contained 0.1 mg/kg of cadmium. Only a few samples from aquatic biota other than oysters have been analyzed and the maximum detected concentration was 0.02 mg/kg (in spot, collected in 1998). In 2001, samples of blue crab, croaker, spot, and hard clams were found to contain cadmium levels lower than the detection limit (0.01 mg/kg).

Using conservative assumptions for estimating seafood exposure doses based on the maximum detected concentration of cadmium in oysters, ATSDR estimated a chronic adult dose (0.003 mg/kg/day) and a chronic child dose (0.011 mg/kg/day) that exceeds the chronic oral RfD, 0.001 mg/kg/day for food intake. Because the absorption and distribution of cadmium in the body has been well studied, scientists have been able to predict (using a model) the NOAEL or level of cadmium intake at which adverse health effects would not be expected to result after chronic exposure. The RfD is based on this NOAEL, which is 0.01 mg/kg/day, multiplied by an uncertainty factor of 10 to account for variability between people. A review of most chronic toxicity studies showed LOAELs at doses above 1 mg/kg/day (ATSDR 1999b).

The oyster population in Willoughby Bay is not sufficiently large for any commercial oyster harvest to have reported since 1972, when Virginia first implemented a voluntary commercial catch reporting system (which became mandatory in 1992) (VMRC 2001). For about the last 20 years, any recreational harvesting of oysters has been limited because disease caused a steep decline in the population. Hard clams, blue crabs, and fish are sufficiently abundant that they are commercially harvested. Since 1985, levels of cadmium measured in oyster samples have generally been below 1 mg/kg. Doses associated with these concentrations are well below levels shown to result in adverse health effects. Oysters are reported to bioaccumulate cadmium at substantially higher rates than other marine species, including other bivalves (Dixon et. al 1993). Results from VDEQ's 2001 samples of hard clams, blue crabs, fish, and oysters were consistent with this finding.

Because ATSDR's conservative dose estimates resulted in doses lower than the LOAELs and the NOAEL, oyster consumption is infrequent, and other aquatic biota are expected to contain lower levels of cadmium than those found in oysters, exposures to cadmium are not expected to cause adverse health effects.

Chromium

Chromium is present in the environment in several different forms, including chromium VI and chromium III. Chromium III is an essential nutrient (i.e., required by the human body). The National Academy of Sciences recommends that the adult diet include 0.05 to 0.2 mg/kg of chromium III/day and that the diet of a child (aged 4 to 6) include 0.03 to 0.12 mg/kg/day (recommendations for younger children are lower). Chromium III occurs naturally in the environment and is used in certain industrial processes, while chromium VI is generally produced by industrial processes. Chromium VI is reduced to chromium III in water.

The forms of chromium present in fish and shellfish samples from Willoughby Bay were not specified, but chromium in fish and shellfish is normally present entirely as chromium III. Chromium was only detected in 12 of 41 samples, and the highest concentration was 74 mg/kg. No chromium was detected in any of the fish or shellfish samples collected in 2001 (at concentrations above the detection limit of 0.05 mg/kg). Using the highest reported concentration, ATSDR estimated an adult dose of 0.04 mg/kg/day and a child dose of 0.13 mg/kg/day. While these doses exceed ATSDR's provisional guidance for oral exposure to chromium VI (0.003 mg/kg/day, based on the upper range of the estimated safe and adequate daily dietary intake), they are well below the RfD for chromium III (1.5 mg/kg/day), the type of chromium expected to be present in aquatic biota (ATSDR 2001b; FDA 1993b). Thus, exposure to chromium is not expected to result in adverse health effects.

Lead

The highest detected concentrations of lead in biota samples from Willoughby Bay were 6.19 mg/kg (blue crab) and 2.52 mg/kg (spot), both measured in 1971. A second spot analyzed in 1971 contained 1.35 mg/kg of lead. No samples were analyzed for lead between 1971 and 1985. During much of this period, a fishing ban was in effect in Willoughby Bay due to the upstream release of kepone. In 18 oyster samples collected between 1985 and 1993, lead levels reached only 2 mg/kg, and in 13 oyster samples collected since 1994, lead levels have been below 1 mg/kg. In 2001 samples from oysters and hard clams, the detected concetrations of lead were 0.10 mg/kg and 0.13 mg/kg, respectively. In 1998 and 2001, two spot samples, a croaker sample, and two blue crab samples did not contain levels of lead exceeding 0.1 mg/kg. Based on our understanding of likely fish and shellfish consumption patterns, data from available samples, and our review of the toxicology literature addressing lead, ATSDR concluded that lead levels in fish and shellfish from Willoughby Bay are not expected to cause adverse health effects.

Scientific literature does not reveal a clear threshold level (i.e., a level at which no adverse health effects will occur) for many health effects from lead exposure and there are no MRLs or RfDs for exposure to lead. Correlations between blood lead levels and adverse effects are fairly well understood, however, and are studied to evaluate the potential for adverse health effects (e.g., nervous system effects, impaired neurobehavioral development of children, and hematological effects). The Centers for Disease Control and Prevention (CDC) considers children to have an elevated level of lead if the amount of lead in the blood is at least 10 micrograms per deciliter (μg/dL). Medical evaluations and environmental investigations and remediation are recommended when blood lead levels in children reach 20 μg/dL. Medical treatment might be necessary in children if the lead concentration in blood is higher than 45 μg/dL. CDC considers blood lead levels of adults to be elevated if they exceed 25 μg/dL (ATSDR 1999c).

ATSDR applied an approach that has been devised to estimate blood lead levels from known, media-specific contaminant concentrations. The approach has been developed based on the results of numerous studies that have attempted to correlate environmental lead levels with blood lead levels (ATSDR 1999c, FDA 1993c). The model that has been developed to estimate blood lead levels considers the extent to which lead exposures might cause blood lead levels to rise. ATSDR regards the model as a useful screening tool and used it to evaluate exposures to lead in fish and shellfish from Willoughby Bay.

ATSDR estimated the possible contribution of chronic exposure to lead in fish or shellfish to blood lead levels. Studies indicate that the blood lead levels of adults and children are estimated to increase up to 0.034 μg/dL and 0.24 μg/dL, respectively, for every microgram of lead in food ingested (ATSDR 1999c). Based on this screening approach, chronic exposures to the highest detected concentration of lead (6.19 mg/kg, measured in an oyster sample in 1971) would result in an estimated increase of 26.0 μg/dL in blood lead levels of children and an estimated increase of 7.4 μg/dL in blood lead levels of adults. These estimates, however, are extremely conservative and are expected to overestimate increases in blood lead levels due to consumption of fish and shellfish from Willoughby Bay. They assume that people consumed almost 5 meals per month containing the maximum detected lead level of 6.19 mg/kg, measured in 1971. However, the second highest detected concentration of lead was 2.52 mg/kg, also measured in 1971. All other fish and shellfish samples analyzed for lead have contained concentrations of lead below 2 mg/kg. The fish and shellfish samples collected in 2001 had even lower levels (below 0.2 mg/kg). Chronic exposure to lead levels below 2 mg/kg would be estimated to cause the blood lead levels of children to increase less than 10 μg/dL and of adults to increase less than 2.5 μg/dL. Therefore, adverse health effects due to consumption of lead in fish or shellfish from Willoughby Bay would not be expected.

<u>Mercury</u>

Mercury exists in several forms, including metallic mercury, inorganic mercury, and organic mercury, each of which occur naturally in the environment. Certain microorganisms and natural processes can convert mercury from one form to another, most commonly to methylmercury, a type of organic mercury that can accumulate in the food chain (ATSDR 1999a). Nine samples from Willoughby Bay have been analyzed for mercury. One 1971 sample contained 0.49 mg/kg mercury, but the other three samples from 1971 contained less than 0.04 mg/kg mercury. All five samples collected in 2001 (from blue crabs, croaker, spot, oysters, and hard clams) contained mercury levels below the detection limit of 0.01 mg/kg.

ATSDR's estimated chronic dose for a child (0.0009 mg/kg/day) would exceed the chronic MRL for methylmercury (0.0003 mg/kg/day). The MRL was derived from a study indicating a NOAEL for humans of 0.0013 mg/kg/day, which is higher than the estimated child dose (ATSDR 1999a). Furthermore, no one is expected to be regularly exposed to mercury at the highest detected concentration. This conclusion is supported by the 2001 VDEQ data, in which all reported mercury concentrations were lower than the detection limit of 0.01 mg/kg. Although data on mercury concentrations in shellfish and fish in Willoughby Bay are limited, available data do not indicate that exposure to mercury would result in adverse health effects.

Thallium

Six samples from Willoughby Bay were analyzed for thallium. In 1986, a hard clam sample was analyzed and found to contain 2 mg/kg of thallium. In 2001, a single sample of each of the following species was analyzed for thallium: blue crab, croaker, spot, oyster, and hard clam. In all five of these samples, thallium levels were below the detection limit of 0.3 mg/kg. Chronic exposure to the level of thallium reported in 1986 (2 mg/kg) would result in an adult dose (0.001 mg/kg/day) and a child dose (0.004 mg/kg/day) that both exceed the RfD (0.00008 mg/kg/day). However, the relatively limited available scientific literature reports that the NOAEL for thallous compounds (the forms of thallium most common in the environment) in animals is generally in the range of 0.2 mg/kg/day, 50 times higher than the estimated dose to children and 200 times higher than the estimated dose to adults. Furthermore, the 2001 thallium sampling data suggest that the 1986 measurement is not representative of the concentrations of thallium generally currently present in shellfish and fish from Willoughby Bay. Even at concentrations 10 times higher than the highest value observed (2 mg/kg in clams) no adverse health effects from exposure to thallium would be expected (ATSDR 1992). Further, ATSDR's assumptions likely overestimate the extent to which oysters from Willoughby Bay are consumed, particularly by children.

Zinc

Sixty-two oyster samples from Willoughby Bay have been analyzed for zinc since the 1970s, but a total of only eight samples have been analyzed from blue crab, spot (a popular species of edible fish), croaker (another species of edible fish), and hard clam. The maximum detected concentration of zinc in an oyster sample was 1,440 mg/kg, measured in 1994. The average detected concentration in all oyster samples, however, was 647 mg/kg. The three spot samples available (the first two collected in 1971 and the third in 2001) contained 91 mg/kg, 124 mg/kg, and 5.1 mg/kg zinc (respectively). The 2001 croaker sample contained 4.7 mg/kg zinc. The zinc concentration in a 1971 blue crab sample was 65 mg/kg and 22 mg/kg in a 2001 blue crab sample. The zinc concentration in a 1986 hard clam sample was 38 mg/kg, while a 2001 hard clam sample was reported to contain 8.4 mg/kg.

Scientific literature indicates that zinc bioaccumulates in oysters at substantially higher rates than in other molluscan bivalves. Specifically, research indicates that zinc bioconcentrates in oysters almost 200 times more than it does in soft-shell clams and more than 30 times more than it does in mussels (NPS 1997). Bioconcentration factors have not been identified for hard clams, the type of clams found in Willoughby Bay, or blue crabs. However, a study of zinc levels in oysters and hard clams collected from part of western Florida indicated that zinc levels were 20 or more times higher in oysters than in hard clams (Dixon et. al 1993). Thus, available data suggest that levels of zinc in aquatic biota other than oysters would be expected to be lower than the levels found in oysters.

Zinc is one of the most common elements in the earth's crust and is one of the most widely used metals in the world. Its most common use is as a protective coating for other metals, and it is also present in a number of metal alloys and paints, as well as in domestic wastewater. It is an essential nutrient. Too little zinc in a person's diet can lead to a lowered ability to resist disease and other health problems. Too much zinc in a person's diet, however, can lead to health problems, such as gastrointestinal distress or effects on other human systems. Potential health effects from acute and chronic dietary exposures to zinc are discussed in more detail below.

Because exposure to oysters is expected to be infrequent based on the limited oyster population in Willoughby Bay, ATSDR evaluated occasional, one-time exposures. ATSDR calculated the acute doses to adults and children that would result from a single meal of fish or shellfish containing varying levels of zinc. The following table presents these dose calculations.

Zinc Concentration (mg/kg)	Resulting Acute Dose (mg/kg/day)		Acute MRL (mg/kg/day)	Human LOAELs, Acute Exposure[6] (mg/kg/day)
	Adult (11.4 oz)	Child (6 oz.)		
1,440[1]	6.7	24.5	None	0.5 - 7
647[2]	3.0	11.0		
124[3]	0.6	2.1		
45[4]	0.2	0.8		
22[5]	0.1	0.4		

Notes:
1 - maximum level detected in oysters
2 - average level detected in oysters
3 - maximum level detected in a non-oyster sample, from spot
4 - average level detected in all eight available non-oyster samples
5 - maximum value detected in summer 2001 non-oyster samples, from blue crab
6 - few human studies of acute exposure to zinc are available

Ingestion of zinc or zinc-containing compounds has been shown to result in a variety of gastrointestinal effects and other systemic effects on humans, but extensive data are not available. No oral acute MRL is available for zinc due to insufficient scientific data. The few available case reports of acute exposure in humans have reported short-term health effects at doses as low as 0.5 mg/kg/day. One report of one-time ingestion of 0.5 mg/kg/day of zinc (as zinc sulfate) indicated a transitory decrease in serum cortisol levels. No effects on the adrenal gland itself from exposure to zinc have been reported in humans, and ATSDR did not locate any other studies showing the effects of zinc on adrenal cortisol output (ATSDR 1994).[1] Another case report involved a one-time incident in which military personnel in two army companies inadvertently ingested approximately 7 mg/kg/day of zinc as zinc oxide and 80% of the personnel had gastrointestinal distress and diarrhea. Other case reports suggest gastrointestinal effects might occur after ingestion of zinc as zinc sulfate at doses above 2 mg/kg/day. However, a great deal of uncertainty exists regarding the exposure levels for these acute studies (ATSDR 1994).

Based on the available scientific evidence, estimated acute exposure doses for adults and children eating oysters at the maximum and average detected concentrations are within the range of doses that might result in decreased serum cortisol levels and short-term gastrointestinal effects. However, the oyster population in Willoughby Bay is sufficiently limited that there has been no reported commercial oyster harvest since 1972. The recreational harvest is expected to be very limited, if it exists at all.

ATSDR's conservative estimate of the adult dose resulting from acute exposures to concentrations of zinc detected in eight available samples from other aquatic biota suggests that a temporary decrease in serum cortisol levels might occur, on the basis of evidence from one study. ATSDR's conservative estimate of the acute child dose resulting from exposures to seafood species other than oysters exceeds zinc doses reported to cause a short-term decline in serum cortisol levels and some of the doses that have reportedly caused temporary gastrointestinal distress. However, 2001 samples from non-oyster species contained levels of zinc lower than those reported to cause these temporary effects. The limited data that exist make it difficult for ATSDR to evaluate the representativeness of the available non-oyster samples. Therefore, ATSDR concludes that if there is consumption of Willoughby Bay biota containing zinc levels similar to those previously reported in oysters or those reported in other fish and shellfish species prior to 2001, temporary effects might result, but no lasting health effects would be expected.

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[1] Cortisol is a hormone secreted by the adrenal cortex that plays a role in regulating blood pressure, cardiovascular function, and the body's use of proteins, carbohydrates, and fats. It is normal for cortisol levels to rise and fall during the day; they are usually at their highest in the early morning and at their lowest around midnight. Cortisol is also secreted in response to stress, increasing the blood sugar level and reducing inflammation, among other effects (MEDLINEplus 2001; Stöppler n.d.).

ATSDR also considered longer-term exposures by calculating the chronic doses to adults and children that would result from chronic ingestion of fish or shellfish containing zinc. The following table presents the results of ATSDR's chronic dose calculations.

Zinc Concentration (mg/kg)	Resulting Chronic Dose (mg/kg/day) (about 5 meals/month)		Intermediate and Chronic MRL (mg/kg/day)	Human LOAELs, Intermediate Exposure[6] (mg/kg/day)
	Adult	Child		
1,440[1]	0.72	2.52	0.3	0.7 - 4.3
647[2]	0.32	1.13		
124[3]	0.06	0.22		
45[4]	0.02	0.08		
22[5]	0.01	0.04		

Notes:
1 - maximum level detected in oysters
2 - average level detected in oysters
3 - maximum level detected in a non-oyster sample, from spot
4 - average level detected in all four available non-oyster samples
5 - maximum value detected in summer 2001 non-oyster samples, from blue crab
6 - intermediate LOAELs are reported because few human studies of chronic exposure to zinc are available

Few studies of chronic exposure to zinc have been performed. For this reason, the MRL for intermediate exposure to zinc, 0.3 mg/kg/day, has also been adopted as the chronic MRL. The MRL is based on a study of human exposure to zinc that reported hematological effects (decreased hematocrit, serum ferritin, and erythrocyte superoxide dismutase activity) from exposure to 1 mg/kg/day zinc (0.16 mg/kg/day from dietary sources and 0.83 mg/kg/day from dietary supplements). Thus, the lowest observed adverse effect level (LOAEL) in humans of 1.0 mg/kg/day was derived. Other human studies have shown decreased serum HDL-cholesterol ("good cholesterol") as a result of intermediate exposure to doses ranging from 0.7 mg/kg/day to 4.3 mg/kg/day zinc (ATSDR 1994).

Based on the assumption that people consume fish and shellfish from Willoughby Bay about five times per month, adult and child doses resulting from chronic exposure to the highest detected concentration of zinc in oysters and the adult and child dose resulting from chronic exposure to average levels of zinc detected in oyster samples exceed the MRL. However, consumption of oysters is thought to be uncommon and to occur substantially less frequently than the conservative assumptions ATSDR used in its dose calculations. Furthermore, people are unlikely to consistently consume the maximum zinc concentration measured in oyster samples. Regular exposure to oysters from Willoughby Bay is no longer possible, as the oyster population is very limited. Children exposed to the average concentration of zinc detected in oyster samples in fewer than three 4-ounce meals per month (or four and one-half 4-ounce meals per month during the 8 months of the year when fishing and shellfish harvesting would be likely to occur) would receive zinc doses below the lowest LOAELs and would not be expected to experience adverse health effects.

The estimated adult and child doses resulting from chronic exposure to levels of zinc measured in available clam, crab, and fish samples are below the MRL. Samples from these biota are limited, but even if zinc levels were twice as high as the maximum detected concentration, adverse health effects from chronic exposure to these biota would not be expected to occur.

References

Agency for Toxic Substances and Disease Registry (ATSDR). 1992. Toxicological Profile for Thallium. July 1992.

ATSDR. 1994. Toxicological Profile for Zinc (Update). May 1994.

ATSDR. 1999a. Toxicological Profile for Mercury (Update). March 1999.

ATSDR. 1999b. Toxicological Profile for Cadmium (Update). July 1999.

ATSDR. 1999c. Toxicological Profile for Lead (Update). July 1999.

ATSDR. 2000a. Toxicological Profile for Arsenic (Update). September 2000.

ATSDR. 2000b. Toxicological Profile for Chromium. September 2000.

Dixon, L.K. et al. 1993. Bivalved shellfish contamination assessment. Prepared for the Sarasota Bay National Estuary Program. Mote Marine Laboratories Technical Report No. 224. January 4, 1993. http://www.mote.org/techreps/244/244.pdf.

U.S. Environmental Protection Agency (EPA). 1997. Exposure Factors Handbook, Volume II, Food Ingestion Factors. EPA/600/P-95/002Fb. August 1997.

U.S. Food and Drug Administration, Center for Food Safety and Applied Nutrition (FDA). 1993a. Guidance Document for Cadmium in Shellfish. January 1993.

FDA. 1993b. Guidance Document for Chromium in Shellfish. August 1993.

FDA. 1993c. Guidance Document for Lead in Shellfish. August 1993.

MEDLINEplus. 2001. MEDLINEplus Health Information: A Service of the National Library of Medicine. Medical Encyclopedia: Cortisol Level.

http://www.nlm.nih.gov/medlineplus/ency/article/003693.htm. Last Updated 3 October 2001.

National Park Service (NPS). 1997. NPS Water Resources Divisions, Water Operations Branch. Environmental contaminants encyclopedia: zinc entry. Roy J. Irwin, ed. July 1, 1997. http://www.nature.nps.gov/toxic/zinc.pdf.

Stöppler, M. C., M.D. n.d. Cortisol: The "Stress Hormone." http://stress.about.com/library/weekly/aa012901a.htm. Undated.